



Science Teaching in Italy, with special attention to experimental work

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1. Introduction

A report to non-Italians on the teaching of science in Italy and especially on the role and practice of experimental work in the schools requires a preliminary short history of what happened in our educational system in the past 50 years.

In 1999 a good deal of organizational autonomy was granted to the schools and the school system changed from highly centralized to more locally centred, in which the central authority maintained the duty of establishing a common curricular core for the whole nation. But even before this law became operative the central control on what was being taught and learnt has never been as firm as it is, for example, in France. In principle, what should be taught in each school grade and for each subject has always been prescribed by the Ministry of Education¹, but the teachers always enjoyed a recognized right called "freedom of teaching": meaning that they were free to develop the general indications as they wished, perhaps even cutting out pieces and referring (or not referring) to textbooks that they themselves had chosen among those available on the market.

In fact, even when at a certain point the official documents stopped being mere lists, became consistently detailed and carried a wealth of methodological advice and suggestions (as in 1979 for the middle schools and in 1985 for the primary schools) and when the change was followed by widespread in-service training, the teachers continued to work as they best could, knew or felt - often in the old way - well knowing that nobody except possibly the headmaster would come to inspect them and offer help if they were in difficulty.

This happened because in Italy the number of inspectors who are experts in disciplinary didactics has always been and still is very low, especially for science. The few inspectors are engaged in a number of other duties. They cannot follow the teaching-learning processes closely. While in other countries visiting the teachers is routine, in Italy the visit of an inspector is an exceptional (and usually ill-boding) event.

We can add to the picture the idealist creed that inspired the last big organic reform of the Italian school system (in 1923!) according to which "who knows knows how to teach". The longlasting loneliness of the Italian teachers is perfectly consistent with this idea.

Now the idealist creed is thrown out but we are still suffering its consequences. If we except the primary school teachers whose professional education terminated until a few years ago at the age of 18, the vast majority of Italian teachers possess a disciplinary university degree but no specific training for teaching. University-level courses for training teachers for primary and secondary schools started in Italy in academic year 1999-2000, many years late compared with the other European countries.

As in many other countries, the mean age of Italian teachers is about 50: the vast majority has been educated the old way.

2. Elementary (or Primary) School (6 to 10 years old, extremes included)

Most primary school teachers who are now teaching finished their formal education in special schools where the sciences - especially natural sciences (animals, plants...) and hygiene - were taught as information.² The curricula of the present higher education courses for primary school teachers include the didactics of science and, more or less extensively depending on the institution, science practicals tuned to the age of the young pupils, but the generational turnover of teachers in the schools is slow.

New curricula, prescribed in 1985, emphasised the importance of teaching science. A diffused updating of teachers produced improvements in teaching practice, aided by switching from the former one-teacher classroom to a two- (and sometimes three-) teacher classroom in which each teacher teaches her/his most congenial area. Honestly it must be said that among the Italian teachers the primary school teachers are the most open towards innovation; hands-on science activities of the pupils are quite common.

But still, the quality of science teaching is quite variable from place to place. Excellence can be attained where the headmaster and the school staff are especially well prepared and interested and/or if the school can establish a cooperation with a group of researchers in the field of didactics of science.

¹ In the old days mostly in "table of contents" style, with more detail in later years when extensive comments and didactical strategies were included.

² An unquantified percentage of primary teachers also holds a university degree, most often in Pedagogy.

A reform of the school system dated 2003 confirmed the status of science since the beginning of primary school. The new system was introduced in the first grade last year. Data on the change are not available yet.

3. Middle (or lower secondary) School (11 to 13 years old, extremes included)

Until 1963, when the structure of this part of the school system was partially modified, science was not taught in the middle school. In 1963 the minimum school leaving age was raised to 14 years, a former pre-vocational school was abolished and a new unified middle school was established with two new subjects: "Maths and Science" and "Technology". "Maths and Science" was initially taught, with practically no updating, by the maths teachers who already belonged to the school staffs. In later years other teachers entered the subject: most of them with degrees in biology and natural sciences, very few in physics and chemistry.³

How was the new subject taught? Initially labs and equipment for experimenting did not exist except in the buildings that had housed the abolished pre-vocational schools but, even in those cases the equipment was more technology oriented than science oriented. The schools might have been provided with some money but lacked the expertise that would allow them to spend it wisely. It's a fact that in most middle schools the science labs have always been very poor and badly equipped. Add the fact that an appreciable percentage of the teachers had very little knowledge of science,⁴ and you will understand that practical work in the science lab, although officially advised, was almost never performed. It was usually entrusted to the teacher of Technology until in recent years Technology was diverted from practical work to informatics.

In 1979 the teaching programmes were changed, again without the support of proper in-service updating. The subject "Maths and Science" was explicitly renamed "Maths, Chemistry, Physics and Natural Sciences". The new science curriculum prescribed 6 teaching periods a week, in which "the time devoted to maths and to the sciences should be equally distributed" with the note that "An experimental approach (to science) is considered fundamental and is more important than the teaching of all the topics".

In 1982 AIF made an enquiry³ on how science was taught after the introduction of the new programmes. Here are the results that for experimental work.

Does a lab exist in your school? 61% say "yes", but only 52% of these "labs" were equipped for practical work performed by the pupils.

Do you have the means to perform demonstrative experiments? 100% say "yes" but the existing equipment is considered satisfactory only by 17%.

How much time do you devote to experimental work? 0 (20%), 4 periods/schoolyear (10%), 2 periods/month (49%), 1 period/week (7%), 2 or more periods/week (14%), where in some cases the cause of scarce practical work might have been the lack of suitable equipment.

To finish the picture, a 1994 analysis of the middle school science textbooks showed that many reported "experiments" that were only imagined and sometimes impossible. Less than 50% of the examined textbooks presented experimental work as fundamental and offered useful advice for performing it.⁵

The 1982 AIF enquiry is probably the most recent one on science teaching in the middle school, but we can confidently assume that after 1982 the situation did not substantially improve. In fact a recent enquiry in the middle schools of the region of Lombardia showed that in that region more than 80% of the teachers devotes 4 periods/week to mathematics and only 2 periods/week to science and less than 5% of the teachers follow the indications of the official curriculum.⁶ This choice might be driven by the high concern of teachers and parents alike that the pupils be knowledgeable in the maths expected for the upper secondary schools. Concern for science knowledge is much lower: science is considered a minor subject.

³ A 1982 AIF enquiry on a limited sample showed that the teachers possessed a wide range of degrees: 48% in biology or natural sciences, 21% in mathematics, 9% in economics (!), 6% in pharmacy, 5% in geology, 4% in physics, 2% in chemistry and the remaining 5% in others. In the following years economics and pharmacy were excluded. In 2005 the majority is still held by biology and natural sciences. [M. Bosia, P. Violino, "Indagine sull'insegnamento scientifico nella Scuola Media", LFnS **XVII**,1, p.31 (1984)]

⁴ A very recent report on the overall maths and science knowledge of three-year graduates who enlisted in the university courses for teaching showed that the wrong or not given answers of those who held a degree in mathematics were 60% in the physics questionnaire, 69% in the biology questionnaire, 79% in the chemistry questionnaire, 55% in the Earth Science questionnaire. [G. Anzellotti, F. Mazzini, "Il coordinamento delle prove di accesso alle SSIS per gli indirizzi scientifici: primi risultati del test di settembre 2004", Università e Scuola, **X**, 1/R, 2005]. Now if these young people pass the entrance exams they are required to fill their knowledge gaps. Before 1999 filling the gaps was their personal responsibility while teaching.

⁵ V. Cinquini, "L'insegnamento scientifico nella scuola media", LFnS, **XXVIII**,4, p.164 (1995)

⁶ V. Cinquini, private communication.

Starting in school year 2004-2005 the school reform is being implemented in the first year of middle school, as it is in the first year of primary school. For the first time in the history of the Italian school system the new law gives provision for optional activities offered by the schools. A strengthening of science teaching in a "practical work" direction might become one of the offerings if the pupils request it and the school staff agrees. Until now no information is available on this point.

4. Upper Secondary School (14-18 extremes included): the Lycea

4.1 Reforms

The above described reforms of the Italian school system only touched the primary and middle schools. However in the last decades of the 20th century the upper secondary schools did not remain unchanged. The history of how they changed is quite intricate and peculiar. Probably no other European country can recount a comparable history.

The pressure towards change in the Lycea (the schools that historically provide a pre-university education) was initially fuelled by the change in behaviours and expectations that began in the last years of the '60s and continued through the '70s. In those years the government and parliament proved unable to satisfy the new needs, mainly because the political parts did not agree on the character of a new upper secondary. In the one case in which agreement was eventually found the government fell before the new law could be approved.

More recently two different reforms of the entire school system were approved in the lapse of three years. The 2000 law launched by the leftist government was immediately cancelled in 2001 when the right took power. The implementation of the 2003 law, as mentioned above, started in the fall of 2004 in the primary and middle schools but the question of what to teach in some branches of the new Lycea is not settled yet. The start in the upper secondary, formerly foreseen in school-year 2006-07, seems now postponed to school-year 2007-08.

4.2 Reforms under the surface

During the '70s and afterwards the reaction to the blocked situation described above was the explosion of a spontaneous blooming of so-called "sperimentazioni" (experimentations): new curricula designed and planned by the teachers themselves, proposed to the central Ministry and, if acknowledged, implemented in the schools. When the new curricula concerned the entire course of studies they were called "maxisperimentazioni". When they affected only a limited number of grades or subjects they were called "minisperimentazioni". The situation of the Italian upper secondary school became very complex and varied. The monolithic and uniform traditional organization of the different kinds of Lycea - classical, scientific... - was overthrown: indeed it often happened that the same school offered its students the choice between several kinds of courses.

In terms of the teaching of science, in the traditional Lycea

- physics was (and still is) taught together with mathematics - the teacher may be graduated in physics or in maths, but the great majority are mathematicians;
- chemistry was (and still is) taught together with life and earth sciences by a biologist or a naturalist - chemists are not accepted as teachers in these schools.

The schools rarely had a real science lab. Some, but maybe not even all, had a science theatre adequate for demonstrations where the students were seldom (or perhaps never) brought. Science was almost universally taught as bookish theory and physics and chemistry entered the curriculum only in the last three years of the 5-year course.

Some experimentations changed this. They introduced physics and chemistry from the first year and offered the pupils frequent hands-on experimental activities.⁷ These examples might have been borne in mind by the central school authorities when in the mid eighties they devised a strong experimentation exclusively aimed at physics and maths called "Piano Nazionale per l'Informatica" (PNI). The PNI prescribed that for these subjects at least 30% of the school time had to be devoted to labs - not only manipulative experiments but also computer science labs. The schools that volunteered to try the PNI⁸ were granted the necessary funds and the teachers enjoyed extensive updating, especially in computer science.

⁷ The model might have been the Technical Highschool where physics and chemistry are taught in the first two of five years with a strong emphasis on experimental work, but its adoption was also promoted by diffusion of the PSSC and IPS Projects, that had been promptly translated and were available to the teachers.

⁸ An apparently queer feature is that the trial of the PNI wasn't an "all or nothing" affair. Depending on the teachers' availability, it could be implemented in physics or mathematics or both, in the first two years or in the last three.

Another experimentation "from above" called "Brocca" after the name of the man who lead the planning team, was introduced in the early '90s. The Brocca experimentation designed half a dozen new courses, two of them with strong scientific contents and extensive presence of experimental work (at least 30% of teaching time).⁹

Brocca and PNI are still alive and active but (as the traditional lyceum) they will be cancelled by the 2003 reform.

4.3 Enquiries and sampling

During the last decades of the past century the AIF was asked by the Ministry to carry out three enquiries on the teaching of physics in the "sperimentazioni": in 1983-84 on the spontaneous "grass-root" experimentations; in 1990-91 with focus on experimental work in the PNI; in 1996-97 on the still surviving experimentations (most of them PNI and Brocca). This last, quite extensive enquiry was aimed at exploring the teaching styles and also the learning, perceptions and expectations of the students.

In the following we report and comment the main findings of the 1996-97 enquiry.

4.3.1 Teaching styles

Generally the physics teacher did not teach mathematics but, nevertheless, the physics teacher was a mathematician in 55% of the sample.

In average the teachers' time was spent as: 16% preparing and performing experiments in the physics lab; 41% lecturing; 25% testing pupils; 12% discussing with the students on group-shared activities; the rest in offering remedial help.

61% adopted a problem-solving approach (but what this really means is unclear: problematic situations or end-of-chapter style "problems"?); 24% preferred an historical-epistemological approach; 15% an experimental or technical approach.

Learning was mainly evaluated through written papers or oral presentations; but 43% also referred to lab work. Remedial actions were never aimed at practical abilities but almost exclusively at solving end-of-chapter kinds of exercises.

4.3.2 Experimental work in the lab

Facilities and equipment

The scarce use of the lab (16% of teaching time instead of the prescribed 30%) was not justified by scarce facilities: these were usually considered quantitatively satisfactory albeit sometimes not completely adaptable to the curricular requirements.

In fact 45% of the sample reported that in the last two years significant sums of money had been spent on the physics lab and 53% reported using the lab once a week. But the average use of the lab was less than twice a month.

The reasons for not using the lab seemed to be related to its being not adequate or sometimes not existent: in fact 59% of the sample considered it usable but only 39% reported it as adequate and up-to-date with the safety regulations. In other cases it was not a real lab but only a room with equipment.

absence of a lab technician, reported by 60% of the sample;

however, when the lab was unavailable, 21% performed experiments with the students in the classroom.

Average number of experiments per schoolyear

29% reported 4 or more, 38% less than 4, 10% none, 24% no answer.

How the lab was used (when used)

52% experiments in small groups of students, 33% demonstrations, 20% computer simulations (the total is over 100% because the respondents could give more than one answer).

4.3.3 The students' perceptions

In general the students strongly felt the need for practical experimental activities and were unsatisfied when, against the curricular requirements, they were not performed with the desired frequency.

When asked about the most important sources of difficulties in learning physics, lab practicals were at the last place (average 6% with a maximum of 20%).¹⁰ 44% (with a maximum of 89%) felt that their learning would have improved by improving the lab equipment and putting it to better use. To this end an appreciable percentage (14%

⁹ Brocca Scientifico and Brocca Scientifico-Tecnologico. These "heavy" curricula (also in terms of school hours - about 20% more than in the traditional scientific lyceum) are chosen by students who are highly motivated towards science.

¹⁰ The first percentage refers to the entire sample, the second percentage to the students of the same class or school.

with maxima of 36% in schools where the physics timetable was small) was willing to increase the schooltime devoted to physics.

21% (with maxima of 75%) said that their school did not possess a lab. 43% reported that the experimental work was mainly performed by the students in small groups and 36% that it was mainly performed by the teacher.

The perceived frequency of the experimental work was "once a week" (25%), "low" (52%) and "never" (35%). This last figure, compared with the 21% who declares that the lab doesn't exist might indicate that in some cases the lab exists but is not used.

In principle the quite unsatisfactory results of this enquiry that involved classes in which the practical work in the lab was explicitly prescribed would not allow to infer what happens when such activities are not officially foreseen. We can suppose that, excepting (in the best cases) some demonstrations in front of the entire class, in such cases the teaching would be purely theoretical. Furthermore, the double role as teacher of mathematics and physics, combined with the fact that in the final exams a written paper in maths is always present (but a written paper in physics never is) would induce many teachers to severely penalise the teaching of physics and spend the allotted time in favour of mathematics. Talking with students we find out that this does often happen.

5. Actions taken by AIF to improve the teaching of physics with experimental work

In face of this generalised situation that the weak school inspectorate is unable to monitor (not to say remedy), since many years AIF invests resources and energies in actions aimed at promoting good practice in the school lab: mostly involving the upper secondary school teachers but recently also, in collaboration with other Italian science teacher associations,¹¹ in the middle and primary schools.

Our targets are:

a) What should be taught and learnt in school

In the context of the present school reform the Ministry entrusted the compilation of the common disciplinary cores to external groups of experts. AIF was not one of these groups. Nonetheless we decided, together with SIF (Società Italiana di Fisica - Italian Physical Society) and SAIt (Società Astronomica Italiana - Italian Astronomical Society) to draw what we considered would be reasonable indications for physics in the lycea.¹² In this work, that lasted about six months, we were assisted by a central inspector. Consistently with our persuasion that pupils' experimental work in the lab is essential for learning physics, our draft explicitly mentions and requires experimental work. Although unasked for, our draft was presented to the Ministry as an expert contribution and substantially approved.

We are aware that it will take time before these indications will become generalised practice, even in the scientific lycea. Too many teachers are not prepared and our country's unfavourable financial situation will probably make extensive and efficient teacher updating impossible. But we also know that this was not a reason for not trying to enforce the idea that practical experimentation is a fundamental component of learning physics.

b) In-service updating of teachers

Updating fellow teachers is one of the oldest activities of AIF since its inception in 1968. Organising in-service courses has been a qualified activity of our local sections from the beginning but we also have a long experience in organising national week-long summer schools.¹³ In recent years we organised up to four summer schools each year, one of which (and sometimes more) always centred on experimental work.¹⁴

These schools have amply demonstrated their effectiveness¹⁵ but unfortunately each session cannot accommodate more than 30-40 participants.

¹¹ The STAs with which we collaborate are ANISN (Associazione Nazionale Insegnanti di Scienze Naturali) and SCI/DD (Società Chimica Italiana/Divisione Didattica)

¹² AIF has a tradition of designing and discussing physics curricula. It happened several times during the last decades of the 20th century. Until now it has never produced operative results, but it helped the association to become and stay familiar with the complexity of the associated problems and to maintain a high interest in them.

¹³ Starting with one summer school in the early '90s we now organise at least three schools each year. Special mention goes to the Abruzzo summer school kindly hosted by the INFN Gran Sasso Labs.

¹⁴ The 2005 schools were: (1) "Physics and Music", (2) "Electricity and electromagnetism in the lab" (see Appendix), (3) "Of light and sound" (in collaboration with the school authorities of Lombardia), (4) "Historical development of Nuclear Physics". (1) (2) and (3) were strongly lab oriented.

¹⁵ An international inquiry coordinated by AIF (1998) for EUPEN- European Physics Education Network ["The training needs of physics teachers in five European countries - an inquiry", Proc. of the 3rd Eupen General Forum 99 - Part II, EUPEN Consortium, Universiteit Gent] showed that all the mathematicians who declared a "frequent" use of the physics lab mentioned an AIF summer school as one of their most effective updating experiences ["Inchiesta sui bisogni formativi dei docenti di Fisica in cinque paesi europei" Quaderno 10, LFnS, XXXIII, 4, 2000].

c) Teachers in their schools

AIF organises two initiatives aimed at involving physics teachers and their pupils in experimental work in the school.

1) The 29 year-old "Concorso Premio Bonacini" competition proposes the quantitative exploration of physics topics in the lab. The experimental work must be performed by "the teachers with their students". The competition offers two distinct sections, for the upper secondary and for the middle schools. The participation of the middle schools is usually very low and occasionally null, while the contributions coming from the upper secondary schools oscillate between 2 and 15, the number depending on the topic. The competition offers glimpses of what could be possible in the school if experimental work was more diffused and also, through the number of contributions, the popularity of the topics. For example the quite successful topics of the last three years, were:

- "Push and be pushed, pull and be pulled". Quantitative experiments with interacting bodies. (2002-2003, 12 participants)

- "To obey or not to obey? Experimental inquiries on materials and apparatus that do not "obey" Ohm's law". (2003-2004, 15 participants)

- "Energy transfers, work, power: how much do you spend? how much do you obtain?" (2004-2005, 7 participants)

2) The "Giochi di Anacleto" (Anacleto's Games) are a complementary activity of the AIF working group in charge of preparing the Italian team for the International Physics Olympiads (IPhO). They addressed to upper secondary school students. In order to participate the interested schools must enrol. The proposal reaches a large number of schools, not only the about 500 schools whose students enlist for the Olympic selections but also many others. The Games consist of two parts: a theoretical challenge and an experimental challenge in which the pupil is asked to solve a problem using a low-cost device. With the help of ample instructions sent by the organizers the teachers must:

- assemble one copy of the device for each participating student;

- evaluate the students' work (the organizers provide suggestions for marking the students' procedures, observations and conclusions).

Some recent experimental challenges are:

"Can an elastic band be a good dynamometer?" (2004) The challenge involved hanging successive weights from the low end of a rubber band, measuring its successive lengths when increasing and when decreasing the number of weights.

"Bottle with a hole" (2003) The challenge was to find how the relation between the impact point on the table of a water jet spurting from a hole in the wall of a plastic bottle and the decreasing height of the water level in the bottle in two different settings: the bottle is open, the bottle is closed but a long drinking straw is inserted in the bottle's cap.

"A strange floater" (2000) The challenge was to find the ballast that would allow a disposable plastic drinking glass to float with a predetermined water-line in an unknown liquid. The procedure involved measuring the density of the liquid, calculating the ballast and trying out the result.

d) Students

The AIF Olympic group also organises a seven-day summer stage for the younger students that participated in each year's Physics Olympics selection. The stage aims to improve the youngsters' problem-solving abilities, both theoretical and experimental. About 20 students participate each year.

Appendix

Summer School "Electricity and electromagnetism in the lab" Genova, 11-16 July 2005

Programme:

Monday

Morning - Examination of apparatus for electrostatics and group-work

Afternoon - Transverse waves in a coil versus electric signals in a coaxial conductor - Measuring speed of transmission - Computer simulations - Group-work

Tuesday

Morning - Generation and reception of electromagnetic waves and group-work

Afternoon - Assembling a spark transmitter and a coherer receiver - Measuring the radiative resistance of a small antenna - group-work

Wednesday

Morning - Theory and assemblage of a crystal-and-diode radio - Reception of an amplitude modulated signal - Group-work

Afternoon - Fieldwork: outdoors trials of the AM radios

Thursday

Morning - Experiments with opto-electronic devices (photodiodes, photoresistors etc) - Transmission of information by optical fibers - group-work

Afternoon - Measurement of the velocity of light in an optical fiber - Group-work

Friday

Morning - On-line experiments on electromagnetic induction - Group-work

Afternoon - Measurements of magnetic fields - Group-work

Saturday

Morning - Round Table, final comments and conclusions

Participants: 33, some of them still student teachers.

Final Questionnaire:

Contents and methods		no answer	not enough	acceptable	fine			
a-	The treatment of topics was	4		2	27			
b-	The theory was	4	2	17	10			
c-	The lab was	4		4	25			
d-	The time reserved to practicals was	4		4	25			
e-	The time reserved to discussion was	4	4	9	16			
Usefulness: Evaluate the following from 0 to 5		n.a.	0	1	2	3	4	5
a-	Was the course up to expectancies?	5			1	10	13	4
b-	Was the interaction with colleagues useful?	4		2	1	4	6	16
c-	Was the interaction with lecturers and tutors useful?	4				1	6	22
d-	Did you learn new procedures?	5		1		3	10	14
e-	Did the course address your difficulties?	4		3	3	9	11	3
f-	Was the course helpful for your teaching?	4			2	2	16	9
Overall evaluation: Evaluate the entire course from 0 to 5		n.a.	0	1	2	3	4	5
		5				1	16	11
Suggestions: If A.I.F. repeats this course in other towns what would you change?								
a-	in the topics:							
b-	other:							
Suggest topics for other summer schools you might wish to go to.								
Answers: Thermodynamics (8), Optics and wave optics (7), Basic Electronics (6), Physics for middle schools (4), Nanotechnologies (4), Quantum Mechanics (3), Relativity (2), Heat (2), Electrochemistry (2), Astronomy (2), Nuclear Physics (1), Energy (1), Basic kinematics (1), Fluidynamics (1)								