SOME PROBLEMS ENCOUNTERED IN THE INTRODUCTION OF INNOVATIONS IN SECONDARY SCHOOL SCIENCE EDUCATION AND SUGGESTIONS FOR OVERCOMING THEM

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Abstract – *This paper discusses some problems in innovating in the context of the school system in Catalonia and Italy. The process leading to reform of secondary education is briefly described. The issue of teachers' interpretations and reactions to the guidelines of reforms and innovations is focused on. For basic science education, two specific innovative teaching proposals about Energy and Motion/Force are briefly described, together with a study of teachers' interpretations of their rationale and guidelines. The main transforming trends of these interpretations are discussed: these indicate that since teachers are major actors in the school innovation process, unless they internalise the proposed approaches, no real, successful implementation in classroom practice will take place. Finally, some guidelines and recommendations are suggested, which will interest education policy makers and teacher education agencies.*

Introduction

The many global changes that have taken place in recent years have questioned all the agents connected with education, especially the educational authorities, about the structure of the education system, the curriculum organization and the content of taught subjects. Consequently, curriculum reforms have been proposed in many countries. New perspectives coming from the areas of psychology, sociology, didactics and the use of ICT for educational purposes have often influenced the orientation of these reforms.

The educational systems in the vast majority of EU countries are involved in innovative processes, framed in the context of the 'knowledge society' scenario as outlined by the European Union Lisbon strategy (Lisbon European Council in 2000) and also linked to educational technologies. These opportunities go well beyond technical aspects, and not only affect the quality of disciplinary teaching and learning processes but also the development of capabilities needed in the new educational framework (e.g. learning how to learn is a widespread knowledge environment). The conventional roles, the rationale and many other features of school education need to go through re-design and reforms: the aims are not only to improve learning of well acknowledged content areas but more importantly to foster effective and lasting learning habits and to make students capable of orienting themselves within the vast bodies of knowledge which are evolving rapidly in many contexts, both within and outside education.

However, reform and innovation depend heavily on the capability of teachers to evaluate, internalise and implement the proposed strategies and content; teachers' professional development is therefore an essential component in the process of redesigning education.

School reforms

The processes of designing, spreading and implementing reform and innovation in school curricula and syllabi are usually long and complex, involving cultural, educational, political, sociological and economic factors. The following sections briefly comment on some recent reform efforts that have been implemented in Catalonia and others that have been proposed for Italy; subsequently, two examples of innovation attempts designed for secondary school science curricula are discussed.

The case of Catalonia

Catalonia, a Mediterranean autonomous region within Spain, has been engaged in curriculum reforms since 1990-92. Responsibility for education in Catalonia lies not with the Ministerio de Educación y Cultura (MEC) (Spanish Central Government), but rather with the Departament d'Ensenyament de la Generalitat de Catalunya (Catalan Autonomous Government). The Catalan Government has full control over its educational system (since the LOGSE, Llei d'Ordenació General del Sistema Educatiu, BOE núm. 238 del 4/10/90) and establishes its own primary and secondary education curriculum, simply bearing in mind some minimal common core requirements.

With respect to compulsory secondary education (ESO - Ensenyament Secundari Obligatori), this competency is laid down by Decree 96/1992 in the DOGC (Diari Oficial de la Generalitat de Catalunya), which regulates curriculum development.

In Catalonia, a theoretical framework for school reform was elaborated by a commission of experts from different areas, the majority of whom are university teachers with different degrees of proximity to the school situation (Coll, 1986). The Commission established the epistemological, psychological and didactic foundations of the new curricula, which underpin the syllabus for every discipline at each school level. The new programs for the disciplinary subjects are developed by external experts selected by the educational authorities; these are usually university teachers specialized in the discipline, or in one educational level. In drawing up a proposal (often elaborated individually) in accordance with the general framework, the experts rely on their professionalism, their educational experience and their knowledge of the school situation: Proposals are usually analysed and evaluated by other experts. Consequently, the content of the new syllabi is not outlined by commissions of experts and/or teachers for the different school levels, nor for the Service of General Inspection, as occurs in other countries. Minor modifications to the initial proposals may be made by the administration but, commonly, the plans are essentially accepted as the expert had drafted them. In recent years, a private version or a draft is usually circulated, with an invitation for in order to receive initial feedback from teachers. The next step is to make public the new program; this appears in the legal bulletin (Diari Oficial de la Generalitat de Catalunya, DOGC) and becomes official to all effects.

The Decree 96/1992 develops what is known as Primer Nivell de Concreció del Curriculum (First Level of Curriculum Specification). For each disciplinary area (including natural science, which comprises chemistry, physics, biology and geology contents) this determines:

a) the general objectives of the subject area;
b) the processes, concepts and attitudes considered as the content of the subject area;
c) the ultimate objectives of the subject area.

The content of these 'first level documents' is so general that no explanation is provided of the specific objectives of each domain or of each theme. It is left to the schools and to teachers to establish autonomously the second level of specification, (sequence and modules) and the third level of specification (design of the materials and classroom action plan). Both levels of specification have to be within the framework of the first level of specification mentioned above.

In implementing the second and third level of curriculum specification, teachers very often follow the outline that educational publishers have adopted in published textbooks.

Some additional documents accompany the program; their main purpose is to clarify the objectives, to guide the teachers on how to teach globally, to elaborate on the priorities at each school level and to provide recommendations on how to organize and implement evaluation activities. These documents are not normative; they are published on the web site of the Education Department and are meant to offer advisory guidance and support.

The case of Italy

Reform of Italian secondary education has been under continuous discussion for about the past forty years and there is still no complete, coherent plan. Some of the key instances are reported here in brief. In 1997, the Ministry of Education announced a global reform of the whole school system, which had remained substantially unchanged for about eighty years (the overall rational being that of the 1923 Gentile reform). The Italian school system is the nation's biggest enterprise: about 90% of the schools are run by the state, and, in total, about one sixth of the population is involved. Since 1962, when a separate middle school was established for all curricula, very many changes have been implemented, but not set in a coherent framework, e.g. about 60% of secondary schools are engaged in various forms 'experimentation' with curricula and courses. The current situation is a school system where many initiatives of excellence coexist with many unsatisfactory situations.

The 1997 reform was based on: a review of what ought to be taught, a radical re-organization of the school cycles (primary, middle and secondary), significant increase in the administrative and didactic autonomy of schools, and a plan for development of educational technologies in all schools. To start implementing the reform, a board of forty 'sages' (acknowledged intellectuals, writers, musicians, university professors, religious representatives, some pedagogues, no school teachers) produced a 500-page framing document. This document emphasises the role of teachers and brings new tasks into play: '…teaching has to become a desirable profession once again, both culturally and socially, thanks in part to new career profiles….'. The main objectives adopted are: integration of disciplinary transmission within a network structure of knowledge; to foster acquisition of practical and operative skills (e.g. use of technologies); to aim at in-depth study of selected topics at each school level; to abandon the traditional scheme of lecture - individual study – assessment, in favour of learning environments based on communication technologies. The first priority is to develop oral/written capabilities in Italian, and a functional knowledge of basic English. The main guideline for science education is to start from phenomenology-based learning and proceed to critical analysis of science and technological development.

Translating these criteria into official operational guidelines was the task of committees and workgroups organised by the Ministry of Education, in the framework of the re-organization of the school cycles and the new school autonomy; the latter was approved in March 1997. Since then several steps had been taken to make the reform plan operative (e.g.. science teachers' associations have proposed examples of a disciplinary syllabus; proposals about specific aspects have been circulated and published in Ministry of Education journals and on the website; committees have debated diverse viewpoints and come up with proposals, etc..). However, during this complex process a new government was elected in Spring 2001, which intends to implement radical changes to the reform process.

Interpretation and implementation of proposed reforms and innovations

In Spain, Italy and probably many other countries, the decision process about what will be taught is driven almost exclusively by experts. In secondary school, the program of each science discipline is usually taught by specialist teachers who often have well established teaching ideas and long experience in teaching the same or similar topics. In this content, the following questions arise: Will the changes introduced by reforms and/or new programs have any impact in the classroom? Is it easy, or indeed possible, to transfer the vision of the external experts to the practitioners trained in the field?

In recent years, studies about communication have received much attention and have emphasized the fact that in the process of transmission of ideas and information many transformations take place. The receivers are not passive agents; they reformulate and understand the information sent by the transmitter according to their beliefs, their preferences, interests, possibilities, etc. (Ogborn, 2002). This happens in all communication (written, oral, audio-visual, etc.) and can indeed have an effect on the transmission of curricular reforms.

So, it is worthwhile to formulate, and try to answer, the following research questions:

How will official dispositions and legal guidelines elaborated by experts be interpreted by experienced teachers? How big will the gap be between the intentions of the emitters and the interpretations of the receivers? What order of magnitude of transformations happen between the communicated and the interpreted?

Five research teams from five European countries have tried to answer this set of questions within a major research project funded by the European Commission, the STTIS project (Science Teacher Training in an Information Society). The project was coordinated by the Universitat Autònoma de Barcelona (UAB) and involved partners from the University Federico II of Naples, University Denis – Diderot of Paris VII in France, the University of Sussex in the UK and the University of Oslo in Norway.

The main hypothesis of STTIS is that, when a teacher implements a didactic innovation proposed by any external designer, that innovation is inevitably interpreted, re-structured, in brief 'transformed' (STTIS 1998, 1999, 2000a, 2000b, 2001a, 2001b). This inevitably happens since, in their school practice, teachers firstly experience logistic and curricular constraints and secondly are influenced by their convictions, beliefs and specific goals. Therefore, when didactic reforms and innovations are proposed, it is useful to study how teachers interpret the guidelines and the overall framework and how they adopt them in their specific contexts.

The reform proposals

The Catalan proposal about 'Energy'

In seeking to answer the above questions, the team from Barcelona elaborated a program, with the same format as the official curriculum, around one of the most common and problematic themes (Tiberghien, 1996, Warren, 1982) in the science curriculum for 14 year-old students in Catalonia: energy. Emulation of the official program was intended to enable analysis of the teachers' process of interpretation. In parallel, a booklet was prepared for the students who would be involved in this quasi-official program. Implementation of the program and any new teaching sequences became possible thanks to the Catalan teachers' autonomy to decide freely what and how to teach.

The program

The objectives to be achieved by students regarding content (concepts, skills or processes and attitudes) were defined. Didactical orientations were added to guide implementation; these included an emphasis on some ideas, the approach to some concepts, difficulties that students would probably encounter and practical recommendations. 'The Program' comprises three aspects: objectives, content and orientation (Pinto and Gomez 1999): this corresponds to the usual way of presenting the first level of description in the National Syllabus in Catalonia (Departament d'Ensenyament, 1992)

The didactical unit 'L'Energia'

Furthermore, a student booklet called *'L'Energia'*, was prepared (Pinto and Gomez 1999): this contained concepts, exercises and practical activities. All of this created a profile that perfectly defines the level and approach that teachers are expected to follow during classroom implementation; the implementation was expected to last for about 3 months.

Problems to address and main features of the innovative strategy

The scope of the innovative sequence is wide, and consequently the present research focuses on some specific parts. One specific problem, already detected in previous studies (Duit, 1981, 1983; Sexl, 1981; Ogborn 1986, 1990; Solomon, 1982, 1983, 1984, 1985; Pinto, 1993) is that students are unable to construct the concept of energy without a sound understanding of energy conservation (Saltiel, 1997), energy degradation and the relationships between the two. Some of the other problems that have already been identified are the following:

1. Teaching energy conservation linked to energy degradation and dispersal of energy is not very common in secondary schools (Kesidou and Duit, 1993).
2. Only studying ideal systems, as is usually the case in many introductory physics courses, does not allow students to conceptualise energy as a tool that is useful for analysing real situations (Arons, 1997, 1999). To be able to relate energy conservation with energy degradation, students should be encouraged to analyse their environment from a scientific perspective and to better understand better the everyday processes.
3. It is a very common procedure for teachers in physics courses to introduce mathematical formulae before analysis of any phenomena from a phenomenological or intuitive point of view (Reif, 1999). In other words, the real processes are remote from physics classes and, moreover, the nature of physics as a science is presented in a distorted manner.
4. Various, often non-scientific ideas about energy related topics frequently appear in the media (Driver andMillar 1985; Ballini et al., 1998). These are expressed in common language (with many deviations and differences from scientific language) and cover many everyday life situations. Energy consumption, waste, or expense, are common terms that may hinder the idea of Energy Conservation.

To address these problems, an innovative didactical strategy was developed for research purposes. The most innovative elements of the strategy are the following:

a. Organisation and the relationship established among the concepts differ from the ‘traditional’ line followed by most teachers and nearly all textbooks. For example, in the Unit entitled ‘L’Energia’, the concept of energy degradation is introduced as a decrease in capacity to do work, and dispersal of energy as the distribution among many particles, which is not the usual textbook approach. Another innovative approach is the establishment of links between degradation and the internal energy of the system (or self energy, after Alonso, 1971), or between dispersion and energy distribution among many particles (molecular agitation) (Boohan and Ogborn, 1996). In addition, the energy degradation of a system is treated in the unit as a particular case of the general tendency of all spontaneous processes of nature (Ogborn 1976, 1986). Therefore, the interrelations are shown between energy degradation and the irreversibility of natural processes and nature's asymmetry.

b. Discussions of phenomena and processes from different points of view, different theoretical frames and/or different levels of analysis (Pozo et al, 1991).
c. Presentation of the same phenomena from macroscopic and microscopic worlds
d. Didactical orientations and exercises aimed at establishing a bridge between languages or registers (scientific and everyday) (Solomon, 1983, Reif and Larkin, 1991).
e. Considerations about the use of mathematical language in physics.

Other critical aspects of the innovation were defined but for the sake of brevity are not included here.

Focus of our research: lines of analysis

The teachers' reactions to the innovative aspects described above were analysed from two different angles (STTIS, 1999):

- work with concepts: different organisation and different interrelations among them;
- fostering the cognitive skills to be used by students when reasoning about phenomena.

Data analysis is guided by these two perspectives, and a qualitative methodology was used to detect teachers' reactions.

In order to obtain information about teachers' views of the teaching sequence presented in the program, 13 semi-directed interviews were carried out with the teachers of the sample (secondary school teachers from different Catalan state secondary schools).

TABLE 1: Secondary school teachers interviewed.

	Number of teachers
No knowledge of the booklet: 'L'energia'	4
Familiar with this didactical unit	9

Teachers' interpretations of the program and the proposal: main findings

Here we report briefly some of the findings concerning the teachers' views of the program:

- Sharp differences were detected between teachers that had only seen the program and those that had also seen the booklet *'L'energia'*. A much better understanding of the purpose of the teaching sequence is demonstrated by teachers familiar with the booklet. Simply reading the program doesn't usually give a clear idea of its content. Teachers are reluctant to introduce concepts or innovative interrelations when they only learn about them from the programs (e.g. internal energy related with heat for secondary school students, coherent/incoherent motion related to work and heat). Arguments about the impossibility of students learning these are common; however the teachers better understand and accept the innovations after becoming familiar about implementation from the booklet written for students.
- The novelty of the presentation or interrelation of the proposed concepts is sometimes not recognised; '*It (the new idea) is already taught usually without stating it explicitly*' is a common argument by teachers.
- Few teachers mention the interest in interrelating the different concepts of this conceptual field; for example, the interview results demonstrate the following:

• Failure to grasp the significance of relating work with heat, internal energy with kinetic energy, etc.
• Energy availability is very weakly linked with the capacity to perform work.
• The concepts of energy degradation and conservation are used simultaneously only by about one third of the consulted teachers.

- The intentions of the program can be misinterpreted when the conceptual meaning of the words is not well understood. For example, a very complex approach may be considered as very general if no recommendations about using mathematics are inserted. Without mathematics, teachers cannot fathom a great level of complexity.
- Some of the concepts are considered to belong to a specific discipline and cannot be explained within another one. For example, internal energy is considered a concept of chemistry that should not be covered in physics courses. Moreover, the concept of internal energy itself is often misunderstood and its use is screened by explanations in terms of heat and/or allusions to the complexity of this concept.

- The usefulness of introducing energy degradation is diversely perceived, sometimes only linked to «real life» and to debates about energy crises and renewable energies.
- Aesthetic considerations about the program have often been found in teachers' comments (e.g. 'integrating heat and work is very beautiful', demonstrating once again this frequently repeated reason for teachers to change their practice.

All these aspects of teachers' interpretation of the program prepared us for possible challenges that might arise during the implementation of the teaching sequence. Indeed, the predicted risks were confirmed when the program was put into practice.

After analysing class observations and video recordings, we detected ways of introducing the idea of energy degradation that are alternative to the one proposed by the didactical unit *L'energia* and are not acceptable from a scientific point of view. The proposal explicitly states the relationships between energy degradation, useful work, internal energy, heat, work and temperature. From classroom observations, it can be confirmed that, when teachers introduce the energy degradation concept, they do not usually draw on other concepts previously treated, unless it is absolutely necessary. Teachers do not explain the difference and interrelation between the concepts of heat and internal energy. Internal energy is called calorific energy or, more often, heat. These concepts are very often used in a misleading way when describing the energy transfers that take place in real processes.

A chapter of the didactical unit is specifically devoted to showing the interrelation between work and heat and, particularly, to showing that both concepts have a parallel status: processes of energy transfer providing equivalent outcomes (Atkins, 1994). During the implementation of the teaching sequence, we noted that both concepts are treated as two entities that are very different ontologically (Lederman, 1992, Desautels, 1998): heat is described as a kind of energy contained in the bodies or is used as the word to express internal energy (an idea already identified for in university physics students, see Pintó, 1993). It is not common to talk about 'losing energy as work' but rather frequent to say that 'energy has been lost as heat'.

In its content, as well as in its didactical orientations, the Program mentions the importance of language. It proposes distinguishing between the common and scientific registers of language and pointing out the meaningful differences in the terms that are common to both. Therefore, in the proposal to be implemented, the need to verbalise ideas is stressed through some specific activities that suggest shifting one word or linguistic expression from common registers to scientific language and vice versa. The intention was to help students to cross domains, to establish a bridge between them, as pointed out by Solomon (1983). However, the response of teachers shows once again how the designer's intentions can be interpreted in different ways. Teachers' reactions to the sample of proposed activities and to suggestions about establishing a bridge between registers of language were in general, rather discouraging. Within different arguments, little effort was dedicated to crossing registers.

The above examples show some of the difficulties involved in implementing curriculum innovations, especially those developed by designers who are not in touch with teachers and/or do not have the opportunity to explain and clarify the deep reasons for the changes proposed and/or, the opportunities do not arise for teachers surmount possible weakness in their scientific background.

The Italian proposal about 'Motion - Force'

For many years the Naples University Physics Education group has carried out research studies about secondary school physics education (Sassi, 1992, 1995, 1996, 1997). During 1997-1998, within the framework of a National Project in Physics Education FISISS (FISISS 1997), the teaching proposal 'Motion and Force' (M+F) was developed (FISISS 2001, 2002); this is aimed at 14-17 year-old students. Since the Italian school system is a centralised one, the proposal has been tested in several secondary schools, at local level. (M+F) addresses three content areas: kinematics, force-motion and friction. These basic topics are usually taught in Italian secondary school physics courses and are also present in the syllabus recently proposed for the 1997 reform.

During 2000-2001, within the framework of another National Physics Education Project, SECIF, (Guidoni, 2001), the proposal was enlarged, optimised and re-designed, becoming a web-area known now as KINFOR (http://www.na.infn.it/gener/did/kinfor/secif/index.htm, SECIF 2001).

The main goal of the proposal is that of helping teachers become aware of learning difficulties commonly encountered by students on the topic of 'motion/force' and to become familiar with real-time lab-work approaches. The vast majority of physics teachers in Italian secondary schools have a university degree in mathematics and in their pre-service education they have experienced few experimental activities or none at all. This goal is achieved through implementation of a net of emblematic didactic approaches and paths addressing some crucial disciplinary and conceptual nodes of the motion/force topic in accordance with the official directions provided by the current physics syllabus.

This emblematic path starts from phenomena well known to students in terms of common-sense knowledge; both conceptual chains and sequences of practical activities are addressed (Balzano et al., 1992; Sassi, 1992, 1995, 1997, 1999). To minimise the risk of interpreting the path's activities as recipes to be followed step-by-step, they are described as a 'script', the teacher and the class being the actors in the dynamics which will develop.

Attention has also been paid to 'crucial details' (Viennot, 2001). Examples of the paths' titles are: 'From regular walking to uniform 1D motion'; 'From rocking back and forth to the harmonic oscillator'; 'Inversion of Motion and Impulsive Forces'; 'Carts up/down ramps and falling objects'; 'Velocity Composition'; 'When friction is at work'. The time schedule suggested for each path is about 5-6 hours, consisting mainly of lab work in a small group setting to foster and support peer learning.

The main didactic features of the proposed rationale can be summarised as:

(a) focus on students' common learning difficulties (Carmichael et al., 1993, Viennot, 1996, Pfundt and Duit, 1998);
(b) emphasis on phenomenological observation, both through the exploration of experimental situations and the change-of-conditions (variational) approach (What happens if ….?');
(c) inference of regularities from the observed trends, to be checked through other experiments;
(d) experimental exploration based mainly on using Real-Time Experiments and Images (RTEI)[1];
(e) emphasis on the PEC (prediction-experiment-comparison) learning cycle; f. integration of diverse activities (such as lab-work, analysis of students' language, elicitation of prior ideas, relating data with models, etc.).

Since the proposal does not constitute a complete syllabus area, other than an overview of the rationale, it offers a set of materials to facilitate interpretation, such as: detailed suggestions for implementing the paths, Notes for Teachers, Students' Worksheets and a commented 'Catalogue' of real-time experiments discussing the main results typically achieved. In the framework of a constructivist paradigm (see for instance Joannert and Vander Borght, 1999), a set of criteria, hints and materials is also presented to help teachers design and implement their own classroom activities.

The innovation instructions (In-In)

To clarify the rationale, goals and didactic intentions of the proposal's example paths and materials, a list of Innovation Instructions (henceforth, In-In) has been produced. The aim is to help teachers compare their ideas, values, habits with the innovation proposed and foster teachers' awareness of the innovation, and, finally, favour its adoption. To this aim, the In-In have been phrased in accordance with the indications for science education included in the above mentioned 1997 school reform. Underlying these In-In are several broad educational objectives, such as: to make explicit the capabilities and attitudes that should be possessed by teachers and whose transfer to students should be fostered; to call attention to teaching strategies made possible by the characteristics of RTEI.

Following is a summary of some examples of the In-In:

– The proposed didactic paths address the most common/robust learning difficulties in 'motion/force' area (e.g.. confusion between trajectory and the position vs. time graph; the negative sign of velocity and acceleration; motion inversions; correlation amongst kinematic representations of motion; velocity vs. position ('phase space') representation of motion; force vs. energy; impulsive forces in hits; transients and motion initial conditions; acceleration sign in the up/down motion of carts on ramps; elastic forces and oscillatory motion; Galilean composition of velocity and reference systems; friction as force; etc.)

– The paths regularly put into practice a rationale called 'from Real/familiar phenomena to Ideal case/models' (R-I). The suggested example paths start with (mainly real-time) experiments exploring phenomena familiar to the students so as to exploit perceptual knowledge and elicit intuitive ideas; they proceed by identifying regularities in the observed phenomenology which are then summarised in rules through 'cleaner' experiments (e.g. minimise friction effects in motion); they proceed by modelling these rules and moving toward abstract/ideal cases represented by simple mathematical models (textbook-like cases/models).

In order to achieve the above goals, the proposed didactic paths make use of the learning cycle 'Prediction - Experiment - Comparison' (PEC), both to help the students express their ideas and reasoning strategies and to ingrain the habit of integrating different types of capabilities.

Moreover, the paths focus on a 'perceptive approach', linking perceptual knowledge to abstract representations such as those of time graphs of physics variables; use RTEI (in this case motion and force sensors) mainly as cognitive tools and not merely as new pieces of lab equipment; implement a mixture of different activities such as real-time experiments, lab-work based on everyday materials, paper and pencil work (numerical and graphical exercises), teacher presentation, etc..; encourage the students to become capable of describing the way RTEI works and explaining the main features of its hardware, software and data display; help the students become aware that, as with other experimental apparatuses, RTEI measures real phenomena; clarify that the data should not be expected to be 'ideal' just because a computer is being used.

How teachers interpret the Proposal rationale and Instructions

The reactions to the proposal of a group of secondary school physics teachers have been studied in the framework of the EU STTIS Project. A qualitative research methodology was adopted: a small sample of around twelve teachers were called upon to implement the proposal in their classes and their attitudes were observed (STISS 1999), while other teachers took part in a semi-structured, in-depth interview, based on a pre-established protocol. The interviewed teachers were: six from Italy, four from Spain, three from France. The Italian teachers had previously attended a 25-hour training workshop on the basics of both the proposal and RTEI (STTIS 1999). Two of the Spanish teachers knew the basics of Real Time systems, while none of the French teachers had any previous experience with them.

A specially designed booklet was produced that briefly describes the proposal, addresses content and related learning difficulties, outlines example paths, rationale and the (In-In), provides practical hints and a possible time schedule. The booklet was proposed to the teachers, who were later interviewed.

The questions addressed in the interview aimed at investigating teachers' opinions about the proposal: the main focus of the interview was that of having the teachers express their opinions on the features they considered 'innovative' and compare the way the content was presented within their normal ways of teaching. Moreover, the interview aimed at investigating the interpretations of the proposed In-In and discovering whether the features that the teachers found appealing suited them and matched the global didactic objectives. (Giberti et al. 2001, STTIS 1999) The process of the interview data analysis was analogous to the one used by the Catalan team. Two grids ('Lines of Analysis', STTIS 1999) were used to analyse the reactions of the teachers:

- Line of Analysis 1: Focus on learning difficulties and construction of concepts and reasoning strategies; emblematic paths leading from well known/familiar phenomena to abstract cases/models (from Real to Ideal).
- Line of Analysis 2: Fostering constructive learning through integration of different types of activities and focus on RTEI.

Main findings and some suggestions

Analysis of the interviews using the above grids allowed us to detect some teachers' tendencies. The results derived from the interviews with the Italian teachers showed:

(1) A shared tendency to focus on and be aware of the need to introduce innovative teaching of Motion/Force and general discontent with the traditional ways of teaching this topic. Detailed discussion revealed that this awareness seemed to refer mainly to kinematics, and a little to the Introduction to Forces area. As to Talking about Friction, teachers showed some uneasiness, as if it was a 'difficult' subject and so they were not prepared to accept innovations; as one teacher said: 'Traditionally, friction is not studied in detail…while we always work on kinematics graphs…'. Only one teacher claimed: '... we usually disregard friction. It could be a way to do every thing all over starting from it'. In the framework of the 'Real to Ideal' rationale, Friction is a very important force to be considered; the proposed paths do not suggest a separation between a Kinematic description and a Dynamic one. The friction force is focused on every time one can see (in the Real Time graphs) its influence. Hence, the teachers' difficulties with this content area, probably linked to traditional ways of teaching this subject, do conflict with the Proposal's rationale, whereby the three content areas (Kinematics, Force and Friction) and the related paths are valued the same and no hierarchy is suggested, the focus being on addressing learning/teaching difficulties.

(2) A shared awareness about the need to elicit common-sense knowledge and to build upon it. On the other hand, when asked about what specific practical tasks in the proposal were suggested for reaching this goal, teachers could not respond adequately.

(3) An awareness only of some parts of the two conceptual chains of actions and reflections underlying the proposed paths: the Prediction-Experiment-Comparison cycle (PEC) and the 'from Real to Ideal' approach.

3(a) As regards the PEC cycle, none of the interviewees mentioned 'prediction' as a valuable tool for eliciting students' ideas and improving proficiency in lab-work, whereas they intended it as a motivating 'learning-through-discovery' approach.

3(b) As regards the 'from Real to Ideal' approach, all teachers, when interpreting it, focused mainly on the initial and final phases: exploration via Real-Time experiments and final presentation of the ideal case. The initial part of phenomenological exploration was valued as a 'motivating' way to gain students' attention '…the students are enthusiastic... but mainly because they say that what is written in the textbook is 'ideal …'. It emerges from the data that weak teacher focus on the 'search for regularities and rules' and 'modelling' phases does affect the interpretations of the proposal rationale.

(4) The conceptual and practical chaining of the paths' activities was not a major teacher focus; they seemed to be uneasy about integrating the activities within the current classroom practice, probably because of various school boundary conditions and constraints.

(5) A strong focus appeared on the Real-Time experiments, but in most cases more as a way of motivating the students than to foster constructive learning: '*… for the students the use o*f computer technologies is very motivating…they were born with computers and are very good with them…they know computers better than me and this is also motivating…for them, it is part of their everyday life'.

As far as the Spanish and French teachers are concerned, most comments confirm the findings outlined above. The differences that appeared may be connected with various degrees of experience with Real Time systems, and may depend on different curricular habits, e.g. a French teacher said: ' … for us, Kinematics is more a tool for studying other subjects than a goal in itself…'. Overall, some French and Spanish teachers claimed that the learning difficulties addressed in the Friction area are not as significant as those in the Force area or are not suited to the students' age group.

The 'triangulation' of reactions to the proposal from the Italian, Spanish and French teachers makes it possible to detect some 'transformations' of the proposal's rationale and of the In-In and allows us to outline some possible reasons. For the sake of brevity these are not discussed here (STTIS 1999).

The above analysis has confirmed that the ways teachers read/interpret written descriptions/instructions of didactic reforms and innovations are very important elements to be taken into consideration from the design stage onward. For instance, several interpretations indicate significant gaps with respect to the proposal rationale and its In-In.

Overall, a strong attraction toward old teaching habits is evident, for example: an inertial tendency to consider the textbook as the main reference even if the teacher is aware that its presentation may contradict with that of the innovation being implemented; a major concern about the actual possibility to implement lab activities and integrate them with traditional presentation; several 'de facto' difficulties in accepting activity based teaching and learning.

The willingness to adopt innovation appears strongly in the 'world of words' of these interviews, but, overall, the innovations seem to be perceived as scattered spots of 'fresh colour' on the 'old' teaching strategies.

On the basis of the above results, we can draw a number of guidelines and suggestions for education policy makers and teacher education agencies (the following list is neither in priority sequence nor exhaustive):

- The In-In need to provide detailed clarifications of the innovation rationale and to specify the educational and cultural reasons for the proposed innovation;
- In-In have to be phrased in such a way as to minimise the risk of their being interpreted as recipes to be followed; their set of orienting criteria needs to be followed by realistic implementation suggestions;
- Appropriate materials are needed to address this last matter;
- In the framework of a constructivist paradigm, the teachers need to be offered a set of materials aimed at helping them accept the proposed reform and innovation and to implement resonant class activities, including appropriate materials addressing 'dissonant' transformations which may occur in class practice;
- The In-In should address explicitly and extensively the way innovations modify, integrate and deal with the 'old' approach.
- The In-In should emphasise problems deriving from traditional teaching, for instance through commented examples of both students' learning difficulties, ineffective teaching strategies and textbook presentations;
- The In-In need to address explicitly the critical details of an innovative approach: e.g. the steps in the conceptual chain, the sequence and order of tasks that need to be accomplished. These critical features regard the internalisation and implementation of aspects which make explicit a coherent resonance with the rationale of the proposed innovation.

Conclusions

The reported studies of the Spanish and Italian cases have shown that internalising school reforms and innovative teaching approaches requires broad acceptance of their rationale, coherent interpretations of their instructions and also the capability to implement them and exploit their potential in different contexts and situations. Teachers need constructive assistance in doing so. In order to adopt the reforms and the innovations successfully, teachers also need to be supported in becoming aware of why they have been proposed and of the problems in traditional teaching approaches that need to be solved. Therefore, the rationale and instructions should be designed and presented so as to take into account teachers' views, convictions, beliefs, interpretations, experiences and ideas about didactic innovations.

It is not enough for educational researchers to present their proposals and support them on the basis of results obtained in the research framework (STTIS 2001b). Every day teachers experience the details of their specific practical, logistic and professional situations, therefore, the adoption of any reform and/or innovation depends heavily on them. In order to facilitate take-up of reform and innovations, it is necessary to offer teachers support materials and emblematic training situations that can help them to internalise the reform/innovation proposed through careful analysis of the teaching strategies they normally adopt and of the shortcomings entailed in following them. An experiential approach is a powerful tool for comparing the 'old' with the 'new' in order to fully adopt a reform.

Educational researchers involved in designing didactic innovations also need to call attention to possible (observed) interpretations and transformations of In-In made by teachers implementing innovations in ordinary conditions, so as to clarify what a take-up process implies and to support/facilitate adoption. Thus, policy-makers should foresee the implementation of appropriate teacher training programs devoted to favouring the take-up of0 innovations and also take into account research-based recommendations.

This situation, far from being specific to our samples in Italy and Spain, has also been observed by other partners in France and the United Kingdom who were involved in the STTIS project: distortions of what official dispositions tried to say should be taken into account.

So we propose that any change included in a new program should be articulated and justified. In many cases, we have found that teachers would need specific training but the most significant matter is to clarify the reasons why there is a need to modify the traditional way of presenting a concept, a sequence and a content area. If we consider that continuous teacher education should largely be reflected in practice (Gunstone, 2001; Pinto 2001; Sanmarti, 2002), teachers make explicit the reasons that made the traditional teaching of a particular subject incorrect, inappropriate or ineffective. It is not sufficient to plan courses aimed at global introduction of curriculum reforms and/or innovations that focus mainly on description of intentions, or courses that focus exclusively on getting teachers' reactions on them. What should be done, in order that the new curricula be implemented, is to plan specific teacher training courses founded on a socio-constructivist framework and on meta-cognitive views. This approach could help to:

- raise teachers' awareness of previous ideas not only about learning processes but also about what is implied by different ways of teaching;

– elicit teachers' own specific conceptual ideas about the scientific subject to be taught and their ideas about problems in teaching it;
– comparing the new approach with the old one so as to highlight the reasons for the change; why should the old approach be criticised and, especially, what can be gained with the new one.
– raise awareness of the use of language in science learning, after recognising what are semantic changes and what are conceptual ones.

In conclusion, in-service teacher education courses need to offer teachers the opportunity to reflect on their own conceptions about the innovative aspects of a program in a way that leads them to accept the new formulation as a better one with respect to the old. In order curriculum reforms and/or innovations to be introduced effectively, it is worthwhile to teacher education initiatives that also rely on research results.

Notes

1. Information on Real-Time systems can be found at: www.vernier.com; www.pasco.com; http://www.cma.science.uva.nl/english/index.html. Here we refer to MBL (Microcomputer Based Laboratory), developed by the Centre for Science and Math Teaching, Tufts University, Medford MA 02144, USA (R. K. Thornton, Director).

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References

Alonso, M. and Finn, E. (1971) *Física. Vol. 1, Mecánica.* Barcelona, Spain: Fondo Educativo Interamericano.
Arons, A.B. (1997) *Teaching Introductory Physics*. U.S.: John Wiley and sons.
Arons, A.B. (1999) 'Development of energy concepts in introductory physics courses.' *American Journal of Physics*, Vol.67, 1063-1067.
Atkins, P.W. (1994) *The Second Law*. New York, Scientific American Books, Inc. cop.
Ballini, P.; Robardet, G. and Rolando, J.M. (1998). 'Construire le concept d'énergie en classe de première S.' *Bulletin de l'Union des Physiciens*, Vol.92(800), 23-40.
Balzano, E.; Guidoni, P.; Moretti, M.; Sassi, E. and Sgueglia, G. (1992) 'Introductory University courses and Open Environment approaches: the computer as a multi-role

mediator in teaching-learning physics.' In H. Mandl and A. Tiberghien (eds) *Intelligent Learning Environment and Knowledge Acquisition in Physics*. Springer Verlag.

Boohan, R. and Ogborn, J. (1996) Differences, energy and change: a simple approach through pictures. *School Science Review*, Vol.78, 13-19.

Carmichael, M.; Driver, R. and Holding, C. (1993) *Research on Students' Conceptions in Science: a Bibliography*. Leeds, UK. Centre for studies in Science and Mathematics Education, The University.

Coll, C. (1986) *Marc Curricular per a l'Ensenyament Obligatori*. Recerca Educativa, Departament d'Ensenyament, Generalitat de Catalunya.

Departament d'Ensenyament (1992) *Disseny Curricular. Ensenyament Secundari*. Generalitat de Catalunya.

Désautels, J. and Larochelle M.(1998) 'The epistemology of students: The 'thingified' nature of scientific knowledge.' In B.J. Fraser and K.J. Tobin (eds), *International Handbook of Science Education*. Kluwer. London, p 115-126.

Driver, R. and Millar, R. (eds)(1985) *Energy Matters*. Leeds, UK: Centre for Science and Mathematics Education, University of Leeds.

Duit, R. (1981) 'Understanding energy as a conserved quantity. Remarks on the article by R.U. Sexl.' *European Journal of Science Education*, Vol.3, 291-301.

Duit, R. (1983) 'Energy conceptions held by students and consequences for science teaching.' In Proceedings of the 3rd Internationsl Seminar on '*Misconceptions an educational strategies in Science and Mathematics*'. (pp. 316-321). Ithaca, N.J.: Misconceptions Trust.

FISISS Project (2002) *Proposte didattiche su Forza e Movimento. Le tecnologie informatiche nel superamento di nodi concettuali in Fisica*. Co-ordinated by M. Michelini, Lorenzo Santi e Rosamaria Sperandeo. Editrice Forum 2002

FISISS Project (Formazione in Servizio Insegnanti Scuola Secondaria Superiore) (1997), coordinated by P. Guidoni. Unpublished Proposal by Physics Education Research Groups of Milano, Modena, Napoli, Palermo, Pavia, Torino, Udine.

FISISS Project (Formazione in Servizio Insegnanti Scuola Secondaria Superiore)(2001), coord.inated by P. Guidoni. ESPB. Materials at http:\\www.uniud.it\cird\index.html (passaword required).

Giberti, G.; Monroy, G.; Testa, I. and Sassi, E. (2001) 'Teachers' interpretations of a proposal on 'motion and force.' In *Secondary School: Transformations Of Didactic Intentions*, Proceedings of the International Conference *Physics Teacher Education Beyond 2000*. R. Pintò and S. Suriñach (eds). Barcelona. CD Production Calidos.

Guidoni, P. (2001) 'Explaining and understanding in Physics.' Proceedings of the International *Conference Physics Teacher Education Beyond 2000*. R. Pintò and S. Suriñach (eds). Barcelona. CD Production Calidos.

Gunstone, R. (2001) 'The education of teachers of physics: contents plus pedagogy plus reflective practice.' Proceedings of the International Conference *Physics Teacher Education Beyond 2000*. R. Pintò and S. Suriñach (eds). Barcelona. Elsevier.

Joannert, J. and Vander Borght, C. (1999) *Créer des Conditions d'Apprendissage*. De Boeck and Larcier.

Kesidou, S. and Duit, R. (1993) 'Students' conceptions of basic ideas of the second law of thermodynamics.' *Journal of Reasearch in Science Teaching*, Vol.29, 85-106.

Lederman, N. (1992) 'Students and teachers' conceptions of the nature of Science: a review of research.' *Journal of Research in Science Teaching,* Vol. 29 (4), 331-359.

Ogborn, J. (1976) 'The second law of thermodynamics a teaching problem and an opportunity.' *School Science Review*, Vol.57, 654-672.

Ogborn, J. (1986) 'Energy and fuel; the meaning of 'the go of things'.' *School Science Review*, Vol.68, 30-35.

Ogborn, J. (1990) 'Energy, change, difference and danger.' *School Science Review*, Vol.72, 81-85.

Pfundt, H. and Duit, R. (1998) *Bibliography: Students' Alternative Frameworks and Science Education*. Kiel, Germany. Institut für die Pädagogik der Naturwissenschaften (IPN).

Pintó, R. (1993) *Algunos conceptos implícitos en la 1ª y la 2ª Leyes de la Termodinámica: una aportación al estudio de las dificultades de su aprendizaje*. (Doctoral dissertation, Universitat Autònoma de Barcelona, 1991). Bellaterra, Spain: Publicacions de la Universitat Autònoma de Barcelona.

Pintó, R. and Gómez, R. (1999) *Teaching About Energy in Spanish Secondary Schools: Teachers' Transformations of Innovations.* STTIS Spanish National Report on WP3. NR3-Sp. Universitat Autònoma de Barcelona.

Pintó, R.; Gutierrez, R.; Ametller, J. et al. (2001) Teachers implementing innovations: Transformation Trends RW4.

Pozo, J.I.; Gómez Crespo, M.A. and Limón, M. (1991) 'Las ideas de los alumnos sobre la ciencia: una interpretación des de la psicologia cognitiva.' *Enseñanza de la Ciencias*, Vol.9(1), 83-94.

Reif, F. and Larkin, J.H. (1991) 'Cognition in scientific and everyday domains: comparision and learning implications.' *Journal of Research in Science Teaching*, Vol.28(9), 733-760.

Reif, F. (1999) 'Thermal physics in the introductory physics course: why and how to teach it from an unified atomic perspective.' *American Journal of Physics,* Vol.67, 1051-1062.

Saltiel, E. (1997) 'Le principe de conservation de l'énergie et le théorème de l'énergie mécanique en classe de première.' *Bulletin de l'Union des Physiciens*, Vol.91, 957-972.

Sassi, E. (1995) 'Esperimenti in tempo reale e didattica della fisica.' *TD Tecnologie Didattiche*, Vol.7, 46-55, (in Italian).

Sassi, E. (1996) 'Addressing some common learning-teaching difficulties in basic physics courses through computer based activities.' *Proceedings of the XVI GIREP-ICPE International Conference*, Ljubljan, 162-179.

Sassi, E. (1997) 'Computer-based laboratory to address learning/teaching difficulties in basic physics.' *Proceedings ESERA Summer School on Theory and Methodology of Research in Science Education*. Barcelona, 55-64.

Sassi, E. and Olimpo G. (1999) 'Teacher training and information technology.' Proceedings of the conference *The Role of Experimental Work and Information and Communication Technologies in Science Learning*. Lisboa. CDROM Forum Educaçao.

Sassi, E. (1992) 'Basic physics education and computer supported open approaches.' In Proceedings of TIE, *European Conference about Information Technology in Education: a Critical Insight*, 271-281. Universitat Autònoma de Barcelona (UAB).

SECIF Project (2001) (*Spiegare e capire in Fisica*, Coord. P. Guidoni). E. Sassi, G. Monroy, I. Testa, S. Lombardi. Insegnare ed apprendere la cinematica e le forze con KIN-FOR. http://www.na.infn.it/gener/did/kinfor/secif/index.htm

Sexl, R.U. (1981) 'Some observations concerning the teaching of the energy concept.' *European Journal of Science education*, Vol.3(3), 285-289.

Solomon, J. (1982) 'How children learn about energy or does the first law come first?' *School Science Review*, Vol.224(63), 415-422

Solomon, J. (1983) 'Learning about energy: how pupils learn in two domains.' *European Journal for Science Education,* Vol.5, 49-59.

Solomon, J. (1984) 'Prompts, cues and discrimination: the utilization of two separate knowledge systems.' *European Journal of Science Education*, Vol.3(6), 277-284.

Solomon, J. (1985) 'Teaching the conservation of energy.' *Physics Education*, 20, 165-167.

STTIS (1999) 'Symposium: teachers' use of innovative sequences.' In M. Komorek, H. Behrendt, H. Dahncke, R. Duit, W. Gräber and A. Kross (eds) *International Conference of the European Science Education Research Association* (ESERA), Research in Science Education. Past, Present and Future, 2 (pp.441-453). Kiel, Germany.

STTIS (Science *teacher Training in an Information Society*) Project Reports: Outline and Justification of Research Methodology: Work Packages WP1, WP2 and WP3, RW0, (1998); The nature of use by science teachers of informatic tools. RW1, (2000a); Investigation on the difficulties in teaching and learning graphic representations and on their use in science classrooms. RW2, (2000b); Investigation on teacher transformations when implementing teaching strategies. RW3, (1999); Teachers Implementing Innovations: Transformation Trends. RW4, (2001a); Teacher training materials favouring the take-up of innovations. TR WP5, (2001b).

Tiberghien, A. (1996) ‚Energy teaching at high school level: a challange?' In M. Michelini, S. Pugliese Jona and D. Cobai (eds) *Teaching the Science of Condesed Matter and new Materials*, (95-105). Udine, Italy.

Viennot, L. (1996) 'Raisonner en physique: la part du sens commun.' A. Bersenghir, H. Caldas, F. Chauvet, J.L. Closset, W. Kaminski, L. Maurines, J. Menigaux, S. Rainson, S. Rozier, E. Saltiel. Louvain la Neuve, Belgium: De Boeck.

Viennot, L. (2001) 'Relating research in didactics and actual teaching practice: impact and virtues of critical details.' In *Selected Papers ESERA Conference* Thessaloniki. Dordrecht Academic Publisher. (in press)

Warren, J.W. (1982) 'The nature of energy.' *European Journal of Science Education*, Vol.3(4), 295-297.