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Abstract

Innovations in science education are increasingly needed to foster citizens' greater scientific literacy. Results in science education research are contributing to a change of views with regard to the content, teaching/learning processes, teaching methods, teachers' role, etc. in science classes. Additionally, technological resources currently available for information transmission and information retrieval have also reached the school, challenging ways of teaching and learning. Teachers feel committed to following new guidelines when selecting and structuring teaching content, when approaching their work in the classroom, when deciding the tasks carried out by students and when choosing teaching materials.

The STTIS research has studied three types of educational innovations in science education, focusing on the nature of their use in class practice, paying special attention to how they are interpreted and transformed by teachers. The innovations studied are: - the introduction of informatic tools, in particular those of computational modelling and simulation and of real-time experiments and display systems; - the construction and/or use of images; - the implementation of innovative teaching sequences for science courses at secondary school level.

All these innovation types have been studied in the context of real classes taught by experienced science teachers, within the five countries participating in the STTIS (France, Italy, Norway, Spain, and the United Kingdom). These teachers were volunteers, and well-motivated to adopting the above-mentioned innovations; thus the main trends observed are a good representation of what happens on a large scale.

In the STTIS project many results have been obtained, mainly through answers to the following questions:

- What are some of the problems and opportunities for the use of informatic tools in science classrooms?
- How do teachers transform the expected uses of such tools? What transforming trends can we conjecture to be involved?
- What are some of the problems and opportunities of the use of images and graphic representations in science courses?
- How do teachers deal with such problems, in the context of innovative teaching? What transforming trends can be inferred?
- What specific requirements are expected of teachers in certain selected and well-defined curriculum innovations in science?
- How do teachers understand these expectations? How do they act in the classroom? What transforming trends can we thereby conjecture?

The results as a whole, including a set of inferred teachers' transformation trends, enable us to state that the introduction and naturalisation of didactic innovations is a complex and lengthy process. During the naturalisation process, many changes of the innovations may occur, since teachers adapt them to specific goals and objective circumstances. Internalising innovative approaches entails broad acceptance of their rationale, and also means becoming capable of implementing such approaches in different contexts and situations

These aspects should be taken into account in order to prevent or minimise reductive interpretations, and to favour the adoption of innovations that is in resonance with the designers' didactic intentions, when explicit, or, if this is not the case, with the potentialities contained within such innovation.

Teachers need positive assistance in coping with the transfer of innovations into actual class-work, since this often implies not minor changes in their role. In order to acquire the know-how needed for a successful adoption of innovations, teachers need to be supported in becoming well aware of why innovations are being proposed and of the problems encountered in traditional teaching approaches.

To favour innovation uptake, appropriate teacher training is a crucial element, even if this alone cannot guarantee teachers' successful adoption of innovation. We need to bear in mind that the uptake of an innovative rationale is transversal with respect to content, even though implementation in class-work calls for specific content to be addressed.

Knowledge of adaptation processes may well help teacher trainers to better focus their courses, and may assist policy-makers in being aware of the need to make courses better suited to their purposes.

Complete information of the STTIS project can be found at http://www.blues.uab.es/~idmc42

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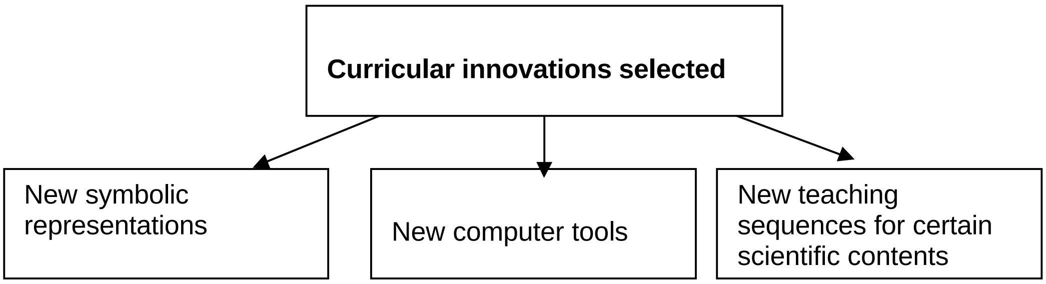
1. Executive Summary

1.1. Introduction

The STTIS project has intended to achieve results for improving teacher formation plans addressed to Science teachers that have to incorporate in their courses curricular innovations. The aim has been to increase awareness of factors which may foster better adaptation to innovations. The curricular innovations to incorporate come from the results of empirical education research, from new theoretical hypothesis about learning and processing information or, from the use of new ways to provide information and to communicate.
Through the STTIS project we have selected the curricular innovations expressed in the scheme:



All the project has been informed by the view that the transmission of information is transformative in its nature, as stated in RW0 (STTIS 1998). The preliminary information is encoded by the first transmitters, which drive their transformation; then it is decoded by the first receiver, namely, the teacher. When teachers use new information in the classroom (a new tool, an innovative approach, an innovative image, etc) it is decoded and thus transformed. Every single act of encoding and decoding leads to a transformation process. Significant changes can take place from the didactical intentions assigned by the designers.

1.2. Overview

The project aims at knowing the conditions for science teachers to successfully implement in their classes some curricular innovations, to document the obstacles that they need to remove and to develop appropriate materials for reducing the effect of unfavourable factors. Its has been adopted the view that innovations are not designed by the teachers themselves being only the transmitters. This is often the situation for teachers in many of the countries, even the level of curriculum' specificity takes large differences among European educational authorities.

Throughout the STTIS project, the implementation of different types of innovations as well the distance between expectation and real actions in classrooms has been analysed.
This has specifically been made in the implementation of:

A) Informatic tools **(Work package 1)**
B) Symbolic representations **(Work package 2)**
C) Innovative teaching sequences for specific scientific content **(Work package 3)**

Teachers, being intermediaries between designers and students, play a major role in selecting, highlighting, interpreting and acting upon any proposed innovation. Therefore, it is worthwhile comparing the expressed aim with the actual use of the activities that should lead to this aim. The STTIS research teams are interested in knowing how teachers transform the innovations encountered and in seeking certain trends in the nature of these transformations. This knowledge could avoid a number of drawbacks with regard to an appropriate implementation.
This has been the main aim of the **Workpackage 4**.

Teacher training activities mainly based on research results of the STTIS project have been designed/prepared to favour the take-up of innovations. The aim has been to increase awareness of factors which may foster better adaptation to innovations. They constitute **Work package 5**.

The interaction with other researchers who have not been involved in the Project is an important element of the dissemination. That's why it has been planned to organize symposia during European Science Education Research Association (ESERA) Conferences and to organize an international Conference in the ICPE and GIREP (Group International pour la Recherche sur l'Enseignement de la Physique) frame. This constitutes **Work package 6**

The extension and diffusion of the results of educational researches such as STTIS results is a very crucial point. Therefore we have summarized them and propose a set of recommendations and guidelines for policy-makers and teacher trainers. This summary constitutes **Work package7**

Methodology

The principle of triangulation indicated collecting a variety of data for each case. Data collected by each country consisted of a practicable and appropriate selection from:

- observation records (researcher notebook) in the classroom
- video recording of student activities (if permitted or suited to the situation)
- recording (audio or video) of teachers' explanations
- copies of tasks given to students (worksheets, tests)
- copies of written work done by students
- interviews with teachers
- discussions/interviews with students

Work content

The STTIS studies on the take-up of innovations have focused on the nature of their use in class practice.
Several aspects which may influence the take-up of an innovation have been identified in the STTIS project; they are summarised here according to the research areas investigated by WP1, WP2, WP3.

1.3. Work package WP1. The use and value of informatic tools

This chapter had been written on the basis of the transversal reports: *The State of Art in the Use and Value of Informatic Tools. RW1.1.* Stylianidou, F., Ogborn, J. and Contini, M., Gutierrez, R., Kolst¯, S. D., Ott., M., Perez, O., Pinto, R., Quale, A., Rebmann, G., Sassi, E., Viennot, L., 1999; and *The nature of use by science teachers of informatic tools*. RW1.2. Stylianidou, F., Ogborn, J. and Balzano, E., Giberti, G., Gutierrez, R., Kolst¯, S. D., Monroy, G., Pérez, O., Pintó, R., Quale, A., Rebmann, G., Sassi, E., Viennot, L., 2000, (http://blues.uab.es/~idmc42/document/index.html)

This workpackage WP1 is devoted to investigate the taking up of innovations designated as informatic tools. It has been articulated in two subworkpackages WP1.1 and WP1.2

1.3.1. State of the art on the use and value of informatic tools in five European countries (Workpakage WP1.1)

The state of the art on the use and value of informatic tools in five partner countries (France, Italy, Norway, Spain and the UK) were examined. The study was concerned with the provision of and kinds of use of computers and informatic tools in secondary schools and more particularly in science and technology classes.
In all countries surveyed the use of generic software seems to prevail. More particularly, word processing packages were said to be used more than any other software package; spreadsheet packages come second and the rest follow. Specific software applications are used in specific study areas.
MBL and simulations are used strongly by some of the teachers but have not yet found a general use. Moreover, modelling remains a minority affair, despite some very strong arguments about its importance.

The impression we gained was that knowledge and experience with computers are spread thinly among teachers; in the best case a lot of teachers have little knowledge and experience with them, but not very many have a lot.
The most important, though obvious, feature in all countries is the rapidity of change. Numbers of and use of computers alter by factors of more than two in only a few years.

The next most evident feature, given the rapid process of change, is the uncertainty about computing having found an integral place in education. That necessarily takes time. Similarly, there are large variations in the experience and knowledge of teachers, going beyond a first acquaintance with computers.
There are real and substantial differences between the countries in actual provision of computers (perhaps a factor of 5 between 'best' and 'worst' cases). But in all the countries there are policies established to develop computing in schools.

1.3.2. The use of selected informatic tools in the science classroom (Workpackage WP1.2)

The WP1.2 research focuses on the use of selected informatic tools in the science classroom. The aim has been to study how teachers transform expected uses of such tools and from this study to conjecture about difficulties and opportunities for the use of the tools in the classroom.
As stated, the informatic tools selected to be of interest to STTIS are basically of two kinds:
computational modelling and simulation; and
real time experiments and display systems.

More particularly, the investigations of the use of these tools vary between partner countries as follows:

- France: simulation tools in teaching optics; and MBL (Micro-computer Based Laboratory) in mechanics
- Italy: MBL in teaching kinematics and forces
- Spain: MBL in teaching energy and kinematics
- Norway: spreadsheets and other simulation tools in teaching motion in force fields; CBL and MBL in teaching thermodynamics, mechanics and electromagnetism
- UK: spreadsheets and other modelling tools in teaching science

Case studies
In accordance to the methodology of Work Package 1 (STTIS 1998a), the above investigations were carried out as case studies of teachers using the tools in the science classroom (see Table 1 for number of teacher case studies per country). Teachers were selected by their willingness to participate and to attempt to make serious use of the tools.

Research questions
The case studies were concerned to identify possible factors which favour or hinder the take-up of the selected informatic tools in science classes, and to investigate how teachers incorporate these tools in the curriculum.

The main questions the case studies address are:

1. *What are the fits (matches) or gaps (mismatches) between the intended or expected use of the tools and the way the teachers actually use them in practice?*
2. *What do teachers identify as more successful and less successful examples of uses of the tools, and what reasons do they have for identifying them as such?*
3. *Are teachers conscious of transforming suggested uses of tools in their own practice, and if so what reasons do they give? If not, are there clues about what may determine the teacher's practice?*

1.3.2.1. Results: Common conclusions across countries about the use of informatic tools in Science classroom

Reading the case studies as a whole, we are struck by the way, despite certain obvious national differences, it would be in general rather easy to imagine any one case study as having arisen in a

different country. The issues which teachers face in constructing viable classroom events ('lessons') have much in common. This appears even though the schools range from difficult and disadvantaged schools to select and advantaged schools; even though teachers' circumstances vary from considerable expertise to relative lack of expertise; despite variations in the supply and availability of informatic tools, despite differences in teaching traditions and practices, and even though national school structures vary considerably.
For these reasons we are encouraged to suggest some tentative generalisations across these data, which may have useful trans-national policy and training implications.

1.3.2.2. Informatic tools are not fully 'naturalised'

Informatic tools have not yet become an 'obvious' or 'natural' and 'taken for granted' tool for science teachers to use. Special arrangements needed to be made, in all participating countries, to identify teachers to take part in the case studies. This was the case despite wide variations in the supply of computers (see RW1.1 STTIS, 1998b), in which Norway, UK and France have relatively good supplies of computing resources as compared with Italy and Spain.

In Norway, with a high level of provision, and central Government insistence on the importance of computing in education, many Norwegian teachers nevertheless do not make much use of computers. The incentive of being provided with specially developed software and training in its use helped to find teachers willing to participate. In the UK and France, considerable efforts had to be made to identify teachers who were spontaneously making use of informatic tools in teaching science. Yet in both countries national policies and educational pressures exist to encourage their use. In Spain and in Italy, teachers whose use of informatic tools could be studied were identified by organising local development projects building on existing work, and providing considerable curriculum support, and sometimes loans of equipment. In summary, teachers using informatic tools regularly in teaching were the exception rather than the rule.
These facts are reflected in the fact that in each set of national case studies, there are teachers who are new, or almost new, to the tools they are using. And in many instances, the individual case studies reflect the teachers' sense of doing something new, of moving into uncharted territory. Those with considerable experience frequently mention their colleagues who have much less experience, and the – for them – relative newness of their own sense of expertise. Many refer to the novelty of the experience for students, whilst often also acknowledging that the use of computers is something students are likely to expect. Even where students prove competent in using computer applications (for example Excel), or have been given systematic training in their use outside the science classroom, science teachers generally regard this as a relatively new achievement.
One consequence of doing something new is that things often get worse before they get better. Mistakes are inevitable; ideas have to be refined and revised. This is nothing other than the well-known *'U-shaped learning curve'*. The case studies, in all the countries, reveal teachers generally aware of this difficulty, and often nervous of it. A few are sufficiently confident to expect to recover from problems encountered; more spend much effort trying to avoid foreseeable problems; some produce lessons which seriously disappoint them or an observer. There are many examples of teachers reflecting on "How I will do it differently another time", showing an active involvement in turning their learning curve upwards.
Teachers by no means reject these kinds of rhetoric often associated with the use of informatic tools: microcomputer-based-laboratory work can develop physical insight and analytical ability; that simulation can reveal the essence of a process; that computational modelling provides new insights into the working of physical theory. Indeed they repeat these claims when justifying what they are doing (though a number are more sceptical). The case studies rather uniformly show such large ambitions hindered by what may look like mundane difficulties, are often the actual consequences of using a given tool, as it happens to be. The arbitrary use of some of the signs; the decisions made by programmers about the precision with which to display results; the way conceptual entities are represented in simulations; the sensitivity of sensors, are all examples of these practical realities which can impinge seriously on other goals.
The fundamental fact that many teachers using informatic tools are doing so without much experience to go on, and sometimes for the first time, necessarily colours any conclusions we can offer. We have found ourselves investigating a dynamic phenomenon, in continual process of change.

The *newness or novelty of the use of informatic tools is widely given a value of its own*. In particular, teachers expect it to motivate students, to provide variety, to simply attract attention, to be "what the students want nowadays". We can say rather little about how the use of such tools might appear when (and if) they become habitual, that is, fully naturalised within the system

1.3.3.Teacher transformations related to the use of computer Tools in science classes(WP 1.2)

According to the data provided by the five National Reports (WP1.2) and the Transversal Report (RW1), teacher transformations should be gathered whilst bearing two aspects in mind:

- teacher adaptation in order to use Computer Tools in their science classes.
- transformation of the use of IT tools expected by teachers in their science classes.

1.3.3.1.Teacher adaptation in order to use the Computer Tools in their science courses

The use of IT tools in science courses presents teachers, and sometimes the school, with a new situation. If teachers assume the use of these new tools, they then should try to:

- Practise the tools in order to acquire expertise in their use.
- Integrate the Computer Tools in the teaching process
- Plan the teaching sequence in order to get access to the computer-room when required (or use portable computers instead).
- Invest the time allowed for Computer Tool use in a reasonable way
- Select phenomena appropriate for analysis through the IT tools

In short, the teachers' adaptation of Computer Tool use in the science courses would benefit from increased flexibility in the use of different educational resources, and in their management of space and time.

1.3.3.2.Teacher transformations of the expected use of Computer Tools in science courses

According to the results, the implementation of IT entails a number of transformations or changes in expected use as an educational tool. Without referring here to the reasons underlying such modification, we can describe the observed changes undertaken by teachers as follows:

- Changes in the goals of proposed activities. Rather than using a given computer tool in a way allowing to achieve certain goals, teachers modify the crucial aspects of the activities that lead to such goals.
- Changes in the approach of some of the tasks carried out during teaching. When the chosen IT tool has been designed according to specific ways for practising certain tasks, it would appear that the approach to some of these tasks has been changed,
- Changes in cognitive demands made to the students. Several observations could be interpreted as a tendency to change cognitive demands originally planned in the curricular innovation
- Changes in the degree of student involvement. The role of teachers and students during class sessions depends often on their skills in the use of computers.
- Changes in the expected use of Computer Tools in order to comply more adequately with teachers' conditions. The use of the tool is not regarded in terms of manageability, but according to teacher's usual practice

1.3.3.3. Factors that may influence teacher transformations

Some factors are identified as influencing teacher transformations:

- The relation with the accepted subject contents. The computer tool is easier to be accepted when the 'distance' between its use and existing syllabus knowledge is not great. Where the proposed use of the tool carries with it new subject matter, which is too distant from that which the teacher expects, both the use of the tool and the new subject matter are likely to be transformed
- Teachers' convictions and beliefs about what they ought to be doing: Convictions about the need to master use of computers differing in the view of who should be making such investment
- Convictions about goals for students: about efficiency. Differences in teachers' beliefs about their own roles, and about what is important for learning, led them to emphasise differing qualities to

computer tools: on the one hand, involvement and activity; and on the other hand, efficiency and the demands placed on students' reasoning.

- Convictions about precision and correctness. The consequences of the fact that computers generally produce definite, clear-cut and often well-presented results are not seen in the same way by all teachers. Differences are related to differences in teachers' convictions regarding the nature of science, as well as the nature of teaching and learning.
- Teachers' customary or habitual practices, and those expected of them: Customary roles of teacher and student. Essentially every case study shows a teacher trying to achieve a balance between the use of the computer, and habitual classroom practices with which that teacher and class are familiar. It is common to select only those aspects of the proposed teaching sequence that fit customary practice. However, a shift towards learner-centred computer use is favoured by openness to changes in the role of teacher and learner.
- Practices in relating theory and experiment. Teachers in all the countries studied were conscious of the need to decide on the sequencing of practical experience and work with the computer
- Integration of computer tools into the teaching process. Many teachers see as necessary to integrate the use of computer tools into a coherent sequence of teaching across several lessons, however, the tools can be used in very different ways to do this.
- Space, time and resources: A very common pattern, in all the countries studied, is to concentrate computing resources in a central bookable suite (or suites) This means that their use and integration into other activities has to be pre-planned. Practice that requires informal spontaneous use does not then develop. *Teaching curriculum and examinations* Teachers see computer tools as competing for time with other essential aspects of the curriculum.. The nature of examinations is particularly critical in determining what teachers feel they must find time for.
- Practices involving colleague teachers. Relatively few case studies report significant interaction with other teaching colleagues.

1.4. Work package WP2. Investigation on the difficulties in teaching and learning graphic representations and on their use in science classrooms

This chapter had been written on the basis of the transversal report: *Investigation on the difficulties in teaching and learning graphic representations and on their use in science classrooms*. RW2. Pintó, R., Ametller, J., & F. Chauvet, P. Colin, G. Giberti, G. Monroy, J. Ogborn, F. Ormerod, E. Sassi, F. Stylianidou, I. Testa, L. Viennot, 2000. (http://blues.uab.es/~idmc42/document/index.html)

1.4.1. Outline of the design for WP2

Three research studies constitute the work in the Work package 2, articulated as subwork packages WP2.1, WP2.2 and WP2.3. Three areas have been investigated about the use of images: students' difficulties in reading images; teachers' awareness and interpretation of students' difficulties; teachers' transformations when using images.

Research questions

To carry out these aspects implies answering the following questions:

1. *What are some of the problems and opportunities of the use of graphic representations in science classrooms that can be anticipated on grounds of prior evidence and/or theory?*
2. *Are these confirmed by students' readings of such representations?*
3. *How do teachers understand the anticipated problems?*
4. *How do they deal with such problems, in the context of innovative teaching involving the use of images and graphic representations?*
5. *What transforming mechanisms can one conjecture to be involved*

The research has been designed to make comparable the design and the methodology followed across the four teams (from France, Italy, Spain and UK). This was done:

- In order to be able to distinguish between difficulties which are more or less strongly related to local cultures and circumstances, and difficulties that are common.
- To make meaningful cross-comparisons of a controlled variety of specific images and contexts. Studying different images under different circumstances (different countries, different schooling levels, etc.), but from the same point of view and frame, turns the common results into more reasonably generalised ones.
- To provide a common frame to analyse students' difficulties. (See the section list of textual/graphical features of images below.)
- To use similar procedures for collecting data: interviews with students before and after being taught, written questionnaires and interviews with teachers about students' answers, etc.

Various aspects have been observed in each area; a global result is that when teachers are called upon to analyse typical examples of students' difficulties with images, their own awareness increases.

1.4.2. Students' difficulties in reading images/documents[1] (WP 2.1)

Since we consider that images are not trivially understandable it is necessary to know which are the features of images that may imply difficulties on interpreting them.

A set of images and graphics has been selected, taken either from specially designed research tasks or from observation of their working with the materials in the classroom (or at the computer). Data were provided on how students do in fact read such visual materials,

1.4.2.1. General trends of interpreting images detected in students' readings.

- Pre-eminence of narrative readings
- Misreading when information is missing

[1] [1] By 'Document' we mean the combination of text and images. Modality refers to the criteria of reliability of the image in terms of being presented as 'true' in a particular context

- Making use of the everyday knowledge
- Giving detailed explanations only referring to graphical signs

1.4.2.2. About the list of features of images associated to detected students' difficulties.

A 'list' of features of the images, designed by the research teams, has shown its usefulness to categorise the students' difficulties. The features of images requiring special attention can be summarised as:

- Images requiring interpretation of the roles of elements representing both real world and schematic or symbolic entities. (R/S)
- Images constituting on-screen graphs, representing data being collected in real-time experiments, where external observable processes and graphic representations need to be related to one another. (RT*)*
  - Ideal versus Real (RT-IvsR)
  - Global versus Local (RT-GvsL)
  - Gestalt (RT- Gest)
  - Axis variables (RT- Var)
- Images whose interpretation requires giving importance to or highlighting certain elements, often in relation to textual/graphical features which make or do not make them salient. (SEL)
- Images containing elements which require appropriate readings of symbols, and which contain examples of synonymy, homonymy and/or polysemy of symbols. (SIM)
- Documents containing verbal elements, included in the image or used as captions, that need to be read as an important part of the whole. (VE)
- Documents containing more than one image, thereby requiring interpretation of the relationships between the different images. (INT)
- Images whose compositional structures are significant and thereby require the reading of spatial distributions and different representational structures. (CS)

1.4.3. Teachers' awareness and interpretation of students difficulties with images (WP2.2)

An essential point when studying the use of images in the classroom is the teachers' awareness and interpretation of the students' difficulties reading images. It is necessary to know which are the aspects of images teachers consider problematic, and how they interpret the difficulties expressed by their students.
In the second subworkpackage, teachers were asked to respond to (comment on) the selected graphics or images, with regard to possible misunderstandings they may create or reinforce in students (or misunderstandings they may avoid). They were asked how they would expect students to read the graphics or images, whether they would expect problems, and what they might be able to do about such problems. The next paragraphs include a short summary of these results:

1.4.3.1. Teachers' comments on students' difficulties

- Low awareness of students' difficulties in reading images
- Focus on disciplinary aspects
- Differences in the diagnosed obstacles
- Difficulties common to both students and teachers

1.4.3.2. Teachers' suggestions for changing the images to overcome students' difficulties

- Addition of verbal elements
- Requirement of actions on relation to the images

1.4.4. Teachers transformations' due to the use of images in class (WP 2.3)

This part of the WP2 deals with the teachers' use of images in class: how they adapt and transform them in the teaching/learning process. We aim to study the characteristics of the changes operated by

teachers on proposed images to be able to conjecture the mechanisms of the underlined transformations.
The teaching strategies chosen for investigation were ones in which visual communication plays a significant role essential to the subject matter and to the nature of the innovation (for example, flow diagram and dispersal of energy, energy conservation in closed system), in which the teaching strategy used needs to take account of students' potential difficulties in reading images (for example, visual representations of optical phenomena; abstract visual representations of energy transfers; graphics generated in real-time interaction with computer simulations or data-acquisition and display systems).
Here are briefly summarised the observed transformations:

1.4.4.1. Transformations related to the use of the visual language

- Changes of the graphic elements
- Changes related to the verbal and mathematical elements
- Changes of the criticism and awareness of students' difficulties with training

1.4.4.2. Transformations related to the didactical role assigned to the images

- Weak addressing of graphical features, particularly of real-time graphs
- Insufficient awareness of didactic advantages of using good quality images
- Weak addressing of possible Textual/Graphical difficulties in reading an image
- Modifying/Eliding/Adding graphical and verbal elements of an image
- Under-exploiting graphical representations to convey new contents

1.5. Work package 3. Transformations when 'adopting' innovative sequences

This chapter had been written on the basis of the transversal report*: Investigation on teacher transformations when implementing teaching strategies*. RW3, Viennot, L. and Balzano, E., Chauvet, F., Giberti, G., Gomez, R., Hirn, C., Monroy, G., Ogborn, J., Pintó, R., Sassi, E., Stylianidou, F., 1999.
(http://blues.uab.es/~idmc42/document/index.html)

1.5.1. Outline of the design for WP3

The study research (Work package 3) addresses the question of the nature of difficulties arising when teachers are expected to adopt an innovative teaching sequence. Our goal was to analyse in detail how teachers' non-neutral interpretation of a proposed teaching sequence may result in transformations with important conceptual consequences.
This perspective should not be taken for trivial nor confounded with the concern of consulting teachers during the process of designing and implementing a new teaching sequence.
The research results on the transformations done by teachers when adopting innovative teaching strategies are important elements to make the design and communication of research-based teaching strategies easier.
We have not tried to analyse "difficulties" as such, but that we refer our observations to precise didactical intentions. If the transformation of a message on its way to its target is to be investigated, this message has to be as clear as possible at the outset, at least for an identified group.
For a given innovative sequence, we locate connections between precise didactic intentions and specific types of action by the teacher. So, on well planned, documented innovations, with specific didactical intentions, have been described in written texts. Actual teaching strategies employed to relate to teachers' conceptual difficulties, to their epistemological views, and to their previous practice have been analysed.

This has been done with six innovative teaching sequences. The corresponding list is:
- ‘Optics at grade 8’ in France
- ‘Colour’ in France
- ‘Motion and Force’ in Italy
- ‘Energy Transfer and Degradation’ in Spain
- ‘Energy and Transfer’ in United Kingdom
- ‘Energy and Change’ in United Kingdom

It is worth stressing that, beyond the differences of topic and context, the selection that we operated is inspired by common views on the teaching learning process, especially the decisive importance of the learner’s conceptual construction and the valuation of coherence. This goes with the fact that the sequences under scrutiny at least witness an effort in such directions.

Research questions

In this WP, the specific questions that are addressed are:

1. *What specific requirements are expected of teachers in some selected well-defined curriculum innovations in science?*
2. *How do teachers understand these expectations? How do they act on these understandings in the classroom?*
3. *What transforming mechanisms can one conjecture to be involved?*

Multiple data of the different types, coming from different sources, have been collected in order to triangulate our observations. They are connected to actual practice to different extents, respectively: what teachers say they will do; (WP3.1), what teachers say they have done; (WP3.3), what teachers do in the classroom. (WP3.3).
The data sources were variegated, each one concerning a relatively small sample of teachers, and being analysed, broadly speaking, in a qualitative register. In all, 171 teachers, from four countries,

have been consulted, this consultation reaching sometimes about twenty hours of discussion and observation for a given person.
Cross comparison between these data sources constitutes a critical basis for our conclusions Having analysed each sequence in the terms proper to it, we have looked for transversal aspects in our results, in order to point to some particular risks of transformation, whatever the topic, in the process of 'transmission' of teaching sequences to (that is, through) teachers.

1.5.2. Transforming trends observed for the studied Teaching Proposals

After comparing findings about different sequences, we attempted at localising rather general and possibly transversal transforming trends. The next paragraphs illustrate some strong points on which convergence is patent.

- Even if judged 'motivating' by a teacher, be it for the pupils or for the teacher her/himself, an innovation may be transformed to a large extent by this teacher. Motivation is not enough.
- Topics dealt with versus what is recommended Some non traditional topics can be neglected, totally or partly. More often, there is a trend to conflate the "new" with the "old" making possible an hypertrophy, and/or incoherence.
- Links- between different approaches or languages, between concepts and activities, conceptual paths - are not put in evidence. There is a quasi-general lack of consideration of links. The recommended order (for instance « from real to ideal »), can be completely inverted in teacher practice. Often, concepts are taught, and activities are organised, in isolation; the fine-grained specification of a chaining between concepts is not taken-up, at the expense of the global rationale, and of conceptual coherence.
- Learners' previous ideas, language and learning difficulties are acknowledged but not actually and consistently addressed.
- Problems with teaching materials (texts, images, activities) likely to reinforce these previous conceptions and learning difficulties are not attended to.
- Students' activity: the intellectual structure (or cognitive dimension) of the activity is not planned in the same detail as the practical aspects.
- The 'Prediction- Experiment- Comparison' strategy is under-exploited
- Observation is valued at the expense of explanation. « Seeing is understanding » seems to be a widely spread slogan. It might go with the « see what I want you to see » syndrome, and be related to the following point, among other possible causes.
- A wish to start from « cleaned » facts is observed.
- A one to one linkage between a given device and a given didactic approach is observed. The maintained use of a classical device drag along with it traditional strategies. The adoption of a new device can foster the - at least partial - take-up of new strategies.
- Critical details of a didactic strategy may deeply affect the impact of a didactic sequence and are also those that are the most difficult to communicate to teachers.

1.6. Work package 4

This chapter had been written on the basis of the transversal report *Teachers Implementing Inovations: Transformations Trends, RW4*, Pintó, R., Gutierrez, R. and Ametller, J. Andresen, O, Balzano, E. Boohan, R., Chauvet, F., Colin, P., Couso, D., Giberti, G., Hirn, C., Kolsto, S.D., Monroy, G., Ogborn, J., Quale, A., Rebmann, G., Sassi, E., Stylianidou, F., Testa, I., Viennot, L. , 2000.
(http://blues.uab.es/~idmc42/document/index.html)

In the STTIS Project, results obtained from the inductive path, followed throughout the in-site analysis with data about an innovation in a country, were crossed and clustered in the National Reports. The cross-checking of different National Reports, corresponding to each type of innovation, led to Transversal Reports RW1, RW2, RW3.
These Transversal Reports (and, when necessary, the 15 National Reports), referring to the implementation of the three types of innovation, provide data for the cross-checking cross-site analysis, whose contrast and comparison will lead to the general clusters. This constitutes what has been called Work package 4 (WP4).
In WP4 we have followed a back and forth strategy to search conceptual coherence between data, interpretation and generalisations.

This methodology led to study whether there are commonly-shared features in the teachers performances when they are faced with innovations. Therefore, the following research question is to be tackled:

> *Can general trends be inferred in the transformation undergone by teachers when facing different curricular innovations?*

An answer to this question should provide us with an insight into teachers' performance following the proposal that their teaching be undertaken differently, or after being given new educational resources.

The methodology used has allowed to group results from the different Phases in order to achieve greater generalisation and conceptual coherency. It has made possible to establish certain general trends from the teachers' sample analysed in our Project. These trends account for teacher behaviour when faced with the innovations proposed by the research groups involved in the STTIS project. These trends are as follows:

- Fragmenting holistic views or approaches
- Modifying small but crucial features
- Reducing the cognitive demands placed on students
- Reducing the scope of activities
- Switching the new proposals to different tasks
- Reducing the quality of classroom interaction
- Reducing language refinement
- Changing the teachers' assigned role
- Adjusting to contextual circumstances
- Adjusting to teachers' personal habits

From a pragmatic point of view and in accordance with the data analysed, it might be said that teachers facing innovations similar to those proposed in the STTIS project will probably show trends in line with those described by the headings listed above.

Such trends have been inferred from a cross-checking cross-site analysis of the teachers' performances when faced with innovations of very different character. We can wonder whether these reactions, as transforming mechanisms that have operated in our teachers, are no more than a particular case of the human reaction when facing a novelty that is not under their control. Future researches, including other human groups, could assess it.

Interpretative aspects of the detected transformative trends have intentionally not been addressed, since our aim was to remain as close as possible to the empirical data, thereby facilitating the potential users of this work with an approach that emphasises teaching reality, i.e., access to current behaviour observed in teachers when implementing innovative proposals in their classes.

Nevertheless, when referring to the related literature, we find several frameworks through which some of the above-mentioned trends can be explained. As they may help teacher trainers to broaden their views when explaining teacher trends in implementing innovations, we can mention here as issues:

- related to knowledge based systems and teachers' belief systems with regard to subject matter content
- related to teachers' beliefs about their own identity and appraisal
- related to teachers' beliefs about teaching and learning
- related to teachers' beliefs about contextual constraints (school, classroom, syllabus, exams, etc.)

1.7. Research based teacher training materials

This chapter had been written on the basis of the transversal report:: *Teacher training materials favouring the take-up of innovations. RW5*,. Sassi, E., Monroy, G., Testa, I., Ametller, J., Andresen. O., Balzano, E., Boohan., R., Chauvet, F., Colin, P., Couso, D., Giberti, G., Gutierrez., R., Hirn-Chaine, C., Ogborn, J., Pintó, R., Quale, A., Rebmann, G., Stylianidou, F., Viennot, L.. 2000. (http://blues.uab.es/~idmc42/document/index.html)

An important outcome of the results, until now presented, is the possibility to elaborate improved teacher training materials based on the research results and, thus, addressed to the most conflictive points or to the most probable transformative mechanisms operating when teachers have to incorporate a particular innovation.

The training materials prepared has been intended as tools to make trainers aware of common ways in which the innovations have been interpreted and transformed in implementation. The aim is to favour a more informed adoption of innovations and to change some of the factors which may influence implementation in class.
For a successful take-up of an educational innovation, several capabilities are required of the teachers:

- to adopt it in resonance with its didactic intentions, when explicit, or, if not, with its potentialities;
- to be open to the modification of previous teaching habits;
- to experiment, flexibly, with the orientation of class learning dynamics according to the innovation's contributions;
- to value effective integration of the “new” approaches with the “old”.

So, the process of successful innovation take-up is not a simple one and teachers do need several types of support. Usually, the teacher gets insufficient support from the context because of: the partial or total lack of training about the innovation; scantiness of expertise among the school teaching staff; lack of or scarce analysis of teachers’ common difficulties in adopting the innovation; insufficient suggestions for organising suitable class activities.

A set of 11 workshops has been prepared for such purposes. Here the list::

France team

- “Constructing a teacher training session about Light and Vision”
- “Constructing a teacher training session about colour”
- “A teacher training workshop: teaching geometrical optics with computer simulation of ray diagram”.

Italy team

- “Teaching kinematics”
- “Teaching Real Time Experiments and Images”

Norway team

- “Computer Simulation”
- “Data Logging”

Spain

- “Teaching about Energy Degradation”
- “The use of images as a didactical tool”

UK

- “Training teachers for innovation: energy transfer and the direction of change”
- “Training teachers for innovation: computer simulation and modelling

1.8. Guidelines for policy-makers and teacher trainers

This chapter had been written on the basis of the report. *Guidelines for policy-makers of teacher training programs RW7*, 2000. Sassi, E., Ogborn, J., Pintó, R., Quale, A., Viennot, L. (http://blues.uab.es/~idmc42/document/index.html)

A useful way to communicate the research results can be to present suggestions for improving the design and implementation of teacher education programs and of didactic innovations in terms of guidelines for policy-makers. To such purpose is addressed the Work package 7. Here we try to summarise in some lines the main recommendations:

Internalising innovative approaches

All didactic innovations to be fully naturalised, i.e. to be thought and used as natural and appropriate strategies/tools for teaching/learning, go through a "metabolic process" that may be long. Internalising innovative approaches entails broad acceptance of their rationale and also means becoming capable of implementing them in different contexts and situations and interpreting them in resonance with their didactic intentions and potentialities.

Appropriate teacher training programs

Teachers need positive assistance in coping with the transfer of innovations into actual class-work. To favour the take-up of innovations, appropriate teacher training is a crucial element, even if this alone cannot guarantee successful innovation adoption by teachers.

Communicating and understanding the reasons for innovations

In order to acquire the know-how needed for a successful adoption of innovations, teachers need to be supported in becoming well aware of why the innovations are proposed and of the problems encountered in traditional teaching approaches. Emphasis on problems deriving from traditional teaching is recommended, for instance through commented examples of both students' learning difficulties and inefficient teaching strategies. The training should address explicitly and extensively why the "old" approaches need to be avoided, modified, integrated with the "new". The use of case studies is strongly recommended.

Linking innovation rationale and critical details

The training should explicitly explain, show and illustrate, through real cases, that without appropriate detailed actions the innovative effects are easily reduced or nullified. The critical details of an innovative approach may deeply affect its impact.

Even so, teachers' choices and actions depend on various factors, which include the disciplinary knowledge, convictions about teaching and learning processes, viewpoint about the role and relevance of lab-work, interests and objectives, image of science, social and communication capabilities, etc. An enlargement of the knowledge on such issues may also have an important benefit.

Focusing on holistic view

The training should focus on helping the teachers become aware of and grasp an holistic view of innovation: topics, concepts, approaches, etc. The aim is to avoid or minimise the tendency to fragment a whole into small unrelated pieces. Emphasis on establishing links between activities, questions, specific episodes, different levels of language, etc, is highly recommended, for instance through analysis of examples and tasks about them.

Special focus is needed on increasing teachers' awareness about careful planning of the cognitive dimensions of class activities as well as of their practical aspects.

Attention to language (oral, written, visual)

The training should extensively explain and show the need to be extremely careful with all types of used language. For instance, this implies: - help to word in scientific terms what is expressed in everyday language, eliciting and overcoming possible conflicts; - attentive care in drawing, reading and interpreting graphs, schemas, diagrams, etc.; - analysis of the understanding of new scientific concepts proposed, to verify their correct adoption

It is also recommended the analysis of teaching materials (texts, images, activities, worksheets, etc.) which may reinforce students' previous erroneous conceptions and learning difficulties. Special attention should be paid to encourage students to interact verbally about the proposed tasks.

Reflections about possible transforming trends in taking up innovations

The training should call attention upon the most common transformations and limited interpretations of innovations done by teachers in implementing innovations in current class-work, as, for instance, the transformations trends listed above. Analysis of examples and case studies is recommended, together with focus on practice, discussing, clarifying, considering alternatives, etc.
Attention needs to be called upon possible sources of conflicts deriving from current curricula/syllabi constraints and contextual circumstances.

By sake of brevity, specific features of the training materials, relevant as critical points of the innovations, are not included in this short Executive summary.

It has been evidenced that the introduction and maintenance of didactic innovation in the school system is a complex process involving many factors that play different roles. Some of these factors are as follows:

- innovation in school, and particularly in science education, is increasingly needed to foster greater scientific literacy of the citizen;
- teachers, the main actors in any innovative didactic process, necessarily do not passively implement the intentions of the innovation's designers and need positive assistance in coping with the transfer of didactic innovation into actual class-work;
- policy makers and agencies in charge of teacher training programs need research-based indications about how the innovation is transformed according to the boundary conditions existing in schools and in response to the teacher's worldview.

THE STTIS PROJECT

SCIENCE TEACHER TRAINING IN AN INFORMATION SOCIETY

2. Background and objectives of the project

2.1. Rationale of the project

The research endeavours to make some contribution to the knowledge of the adaptation of the citizens in the, so called, information society, and thus of the adaptation of individuals to a changing society.

By the Information Society we mean a society with two basic features:

- a great quantity and variety of technological means allowing the sending and receiving of information
- citizens receiving multiple information displayed in different and changing ways and having to take decisions from them.

The Information Society is a site of rapid and fundamental change. The rapidity is extreme, with changes and developments on time-scales of less than a year. And the changes can be sufficiently fundamental to be deemed qualitative, for example placing at the disposal of every citizen world-wide communications, or providing them with tools of analysis and communication previously restricted to small technical elites.

Three relevant key ideas inform the Project rationale:

1) Information has to be understood

Many research studies show that the understanding of relations amongst the different types of information provided is crucial in what is learned. The understanding of content is only part of mastering information; it is also necessary to be able to deal with many types and sources of information and to become agile in adapting to and incorporating innovation.

2) Information is always transformed by the receiver.

The act of understanding is always transformative, as information is selected, prioritised, interpreted, and decisions based on it are taken and acted upon.

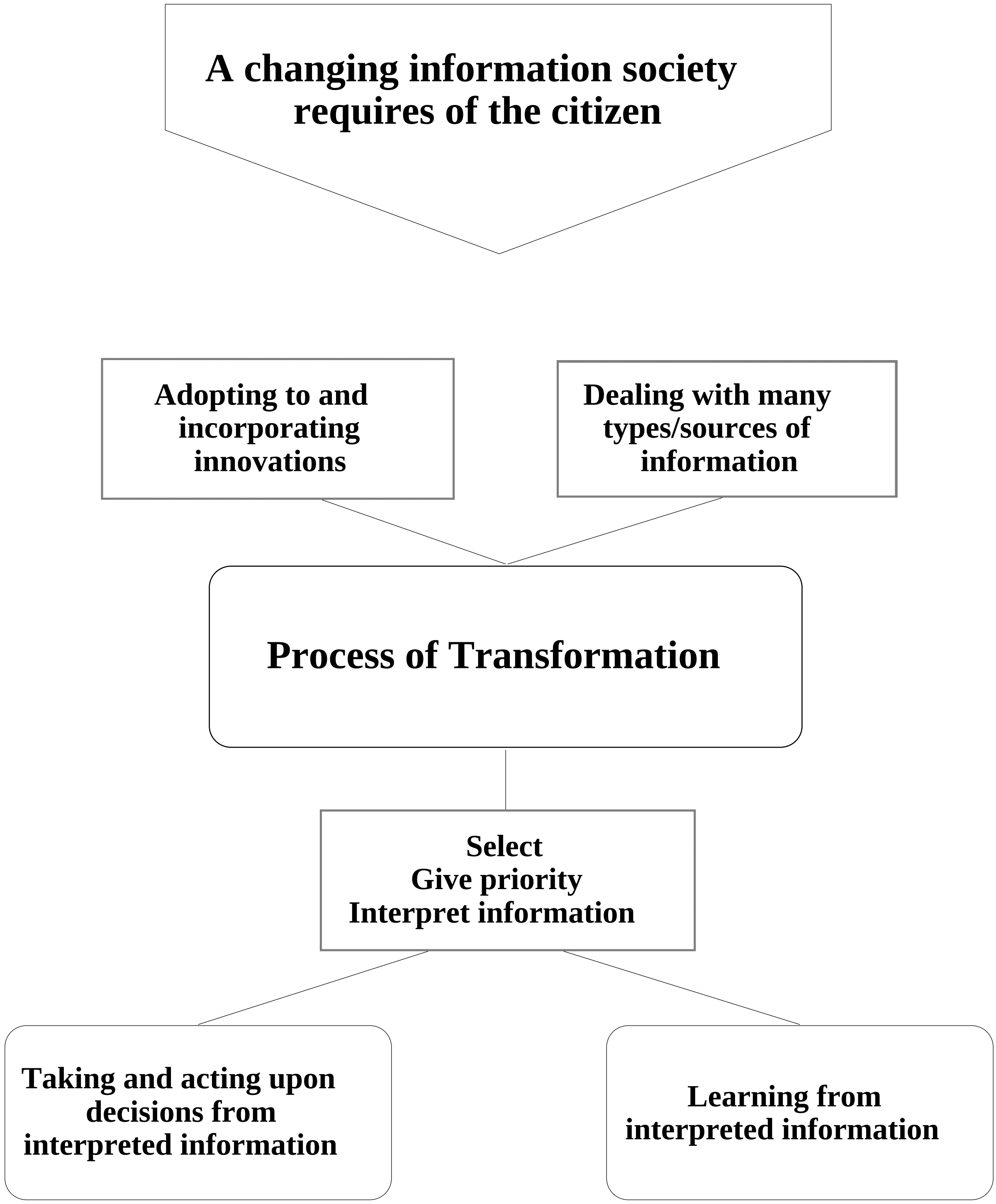
As stated in report RW0 (STTIS, 1998), we adopt a *transformative* view of the nature of communication and change. Communications are not simply 'received' but are re-made, re-constituted, transformed by the receiver. Communication has to be seen as action; as minds acting on other minds which then act in response. Those acts of response are necessarily transformative, making new meanings relate to previous ones. The attentive reader is doing this at this very moment - trying to construct a meaning for this very paragraph which coheres with his or her own ways of thinking. That is one reason why examples are so important in communication and is one reason why much of our research is conducted through case studies.

It is crucial to analyse such transformations when they have to do with the implementation of educational innovation. Rules of transformation have to be compared between countries, to decide which are context dependent and which are general. The need to prepare adequately future science teachers is of high priority because of their role in educating the EU citizen of the current and future Information Society.

3) Information means have to be commanded.

To be able to learn from interpreted information mastery of computer-based tools representing and transmitting information is essential. Basic scientific education is a privileged context to achieve this goal.

The project is addressed to contribute to the mastery of citizens in relation to the use of information means and, in relation with the processes of gathering information that arrive in many different ways, and from which decisions have to be taken.


A changing information society requires of the citizen
Adopting to and incorporating innovations
Dealing with many types/sources of information
Process of Transformation
Select
Give priority
Interpret information
Taking and acting upon decisions from interpreted information
Learning from interpreted information

2.2. Specific objectives

2.2.1. Improving Scientific Formation for a European information society

The White Paper ‘Growth, Competiveness and Employment’ proposes a policy for including the study of Science in general education. It is widely accepted that Science and Technology are fields where Europe has to compete with success. This means that:

- good scientists and technologists have to be prepared
- a good level of scientific literacy is required for all citizens

Scientific and technological information will have an important role in the future society since many of the innovations have a technical character. Each citizen has to be able to use technological means that appear around him. It requires that scientific education for the future citizen has to incorporate, in its courses, the elements that:

- allow the mastery of technical devices (ability and agility to adopt innovations)
- make it possible to understand and interpret messages in all the ways they can be displayed: schemas, icons, graphs, pictograms, etc.

In Science courses it is very common to use symbolic languages: graphs to show the relations between variables, schemas to describe the behaviour of systems, diagrams or charts to make a synthesis of concepts, etc. That is why the ability to use symbolic representations is considered a basic skill for a scientific literacy. Therefore, at present, learning new languages and new codes, as a way to communicate scientific ideas, is a relevant object of study.

The project addresses the contribution of scientific and technological education to the mastery of technical devices and to the learning of different symbolic languages to use for communication. This hints at new approaches to some scientific and technological content and puts an emphasis on some old and new skills.

2.2.2. Making more room for innovation in the training of Science teachers

Whilst the hardware and software for information processing and exchange can be readily purchased and are quickly becoming more and more widely distributed, the use of tools for analysing and representing information requires a rather advanced intellectual level together with high order critical skills.

Teachers are obliged to adapt to this new and continually changing situation. They need positive assistance in doing so. In the absence of positive intervention, education systems are generally rather slow in their response to change. Over a decade, what one can see going on in (for example) a secondary school science lesson may alter rather little. Once trained and with a few years' experience, teachers have acquired a 'stock' or 'repertoire' of knowledge, skills and strategies which they continue to draw upon for many years. If these are not well-adapted to the demands of a new situation, or if no new repertoire is provided, the result may be avoidance of the new situation, or transforming it into something more familiar.
Commonly, the training that many teachers have received has been mainly focused on the learning of classical scientific contents, and of some psychological and educational contents. Only some skills very close to the specific content are usually stressed. So, even interested in up-dating their work, now, starting 1997, we find:

- teachers without adequate experience in activities based on information technology tools
- some of the teachers with resistances to the changes that informatics support represents.
- teachers not well enough prepared to teach how to interpret symbolic representations, because of the difficulty of understanding the device when representations are displayed by computers or because of the difficulty of understanding the underlying concepts.

In the Information Society, the science teachers training processes need to be focused also on the use and experience with information technology tools having in mind that those change the focus and the content of the science and technology curriculum.

2.2.2.1. Fostering mastery of Information Technology tools

There are information technology tools which teachers of science and technology need to master, of which types of very general importance are:

- computational modelling tools
- real-time display tools with computer driven transducers
- simulation tools.

They change what can easily be said, how what is said can be communicated, and even what can be said at all. These types of tools are widely and routinely used in:

- scientific and technological practice
- practical decision-making, professional, commercial and political.
- public communication and media work.

It is a critical failing that none of these types of tool play a central role in the science and technology curriculum, whether as tools to use or as tools whose use by others and the results they produce need to be understood. The economy is modelled by governments and forecasts are presented as statistical data, but the citizen has learned neither what a computational model is nor how to critically read many forms of data graphics. 'Global warming' is modelled computationally, and tested by comparing results with long term trends: again the citizen knows little of how either are done or what trust (or not) to place in them. Examples like this can be multiplied indefinitely.

Such tools have the power to modify drastically the curriculum. They are not merely better ways to do old things, but are also ways to do new things. Large realistic data sets (many available on CD ROM or the Internet) can be analysed. Models of realistic systems (e.g. traffic flow) can be built. Concepts (e.g. of the statistical behaviour of atomic particles underlying the Second Law of Thermodynamics) suddenly become easier and more accessible.

Many common learning-teaching difficulties can be addressed and overcome by activities based on real-time experiments on phenomena well known in terms of every-day knowledge.

But such changes inevitably meet resistance from teachers who have not been trained in the use of such tools and whose concepts of the curriculum are formed by the existing curriculum, which indeed is shaped in part by the very lack of such tools in the past.

The project aims at researching the conditions for Science teachers to command technology based tools and to successfully implement their use in their classes.

2.2.2.2. Dealing better with representations

Information technologies have produced (and will continue to produce) new forms of representing and dealing with information. These new forms do not just make learning or thinking 'easier' or faster; they may change their nature. One example is the use of visualisation to deal with and think visually about abstract structures or complex information, which is very rapidly increasing in use in scientific and technological communities. Another example of visualisation, together now with direct manipulation is educational software such as Cabri-Géomètre, in which the nature of geometrical proof changes for the student, becoming a matter of hypothesis forming and testing. Yet another is the way data representations which change in real time enhance understanding both of the process represented and the nature of the representation. A different kind of example is the possibility of hypertext structuring of information, which profoundly modifies 'linear' reading and learning. A final example is the increased scale on which mathematical operations can be 'chunked' for thought. For instance, with a spread-sheet the user can rather easily try the effect of altering various input parameters, and can see the effects directly, viewing the calculation as an integrated whole.

In many different areas of work, studies are often presented by pictograms, flow-charts and all kind of diagrams. Many kinds of codes are common. For example, it is common for Consulting enterprises to

express ideas, processes by means of pictograms, diagrams of iterative process, etc. Managerial decisions are taken from these representations.
The use of symbols and graphic language is often supposed to be an easier and more efficient way to communicate information. But this idea has to be evidenced, not assumed. A good and faithful interpretation of the information expressed in graphic form needs to be learned.

The proposal tries to contribute, from the starting point of science teacher training, to knowledge of the obstacles to reading graphically coded information and to propose ways to cope well with symbolic languages relevant in an Information society.

2.2.3. Improving the adaptation of teachers to innovations

It is not enough to propose new materials or new tools in order to implement an educational innovation. The most critical phase in curricular innovation is its implementation in school praxis. Teachers play a decisive role as innovation transformers. When teachers are confronted with innovations, they do not act as passive transmitters of the intentions that inspired the originators of a given innovation. A crucial point for successful take up is how they receive the corresponding information.
It is essential to investigate the transformations of new information that teachers tend to make, in order to favour relevant implementation of innovation. This can be done by better adapting the written description of innovation to teachers and by designing new materials and specific strategies for teacher training.

A central issue in our proposal is to analyse teachers' role and possible obstacles when confronted by innovations, and to investigate the factors that influence the quality of take up. A better mutual adaptation between teachers and innovation has to be fostered.

2.2.4. Contributing to a changing society

It is easy to agree that in our society many parameters change more and more quickly. It is also evident that changes in competency are essential.
It is important to know how attitudes and aptitudes of individual develop in order to stand well in a changing society.
But this is not enough. It is also necessary to gain knowledge about how better to implement innovations. The efficiency of diffusion agents has to be improved. New efforts are made everyday to design new ways to present and display information in order they can be well read and understood.
It is already well evidenced, even if not well known, that there is a gap between innovation designers and users. That is, a transformation of intentions is produced in the pathway between them. As it has been said above, information is transformed by the receiver.
The ancient authoritative methods did not avoid it, there were also distortions of the intentions, and furthermore the results were usually very poor. Departments of Humans Resources of companies know it well and have to deal in innovative ways the continuing formation of their employees if they intend to introduce any innovation.
Reaching to implement curricular innovations by Educational Ministry in the school seems not to be too much different than implementing productive, organizational innovations by industrial managers. It seems necessary that, in both contexts, designers of innovations have some transversal and general-purpoise abilities already identified, such as the capacity to choose the representations that are most suitable for the porpoise, or that to optimise the display of conveying information. To such an extrapolation we wish to bring our contribution. This will be done with a to-and-fro approach, from "general" to in-depth "context-specific" analyses, and vice-versa. This is to say, we start from the very specific to be able to go in depth so that we can generalise and go back to have a close view later.

This proposal aims at improving the adaptation of individuals to a changing society, through better knowledge of the circumstances for successful implementation of innovations and, more specifically, to infer some patterns of transformation in the process of implementing innovations.

3. Scientific description of the project results

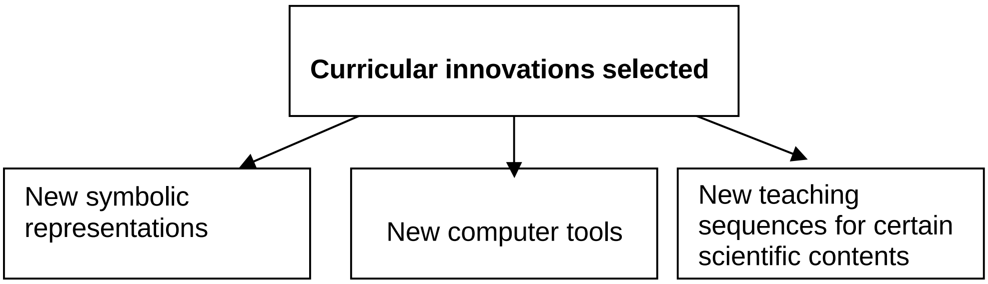
3.1. Introduction

The Information society has brought different innovations in the school that have converged with other changes impelled by research in education: changes of curricula, changes of perception of learning, changes of methodology, etc.

In this way, science teachers are faced with the situation of having to incorporate many curricular innovations as:

- changes on the priority of objectives,
- changes in the selection of scientific contents,
- changes in the teaching strategies,
- changes in the educational resources to use
- changes in the learning activities based on the use of information technology tools,
- changes in the role of experimental work after incorporation of computers in the labs.
- changes in the role assigned to the visual messages
- etc.

STTIS has intended to achieve results for improving teacher formation plans, addressed to Science teachers that have to incorporate in their courses curricular innovations coming: from the results of empirical education research, from new theoretical hypothesis about learning and processing information as well from the use of new ways to provide information and to communicate.
Through the STTIS project we have selected the curricular innovations expressed in the scheme:



Apart from the necessity of introducing innovations in their teaching practice, we have kept in mind that teachers are not the designers of such innovations but only their transmitters The transmission of information is, as stated before, transformative in its nature.
The preliminary information is encoded by the first transmitters, which drive their transformation; then it is decoded by the first receiver, namely, the teacher. When teachers use new information in the classroom (a new tool, an innovative approach, an innovative image, etc) it is decoded and thus transformed. Every single act of encoding and decoding leads to a transformation process. Significant changes can take place from the didactical intentions assigned by the designers.

3.2. Overview

The project aims at knowing the conditions for science teachers to successfully implement in their classes some curricular innovations, to document the obstacles that they need to remove and to develop appropriate materials for reducing the effect of unfavourable factors.
Throughout the STTIS project, the implementation of different types of innovations as well the distance between expectation and real actions in classrooms has been analysed.
This has specifically been made in the implementation of:

A) Informatic tools **(Work package 1)**
B) Symbolic representations **(Work package 2)**
C) Innovative teaching sequences for specific scientific content **(Work package 3)**

Teachers, being intermediaries between designers and students, play a major role in selecting, highlighting, interpreting and acting upon any proposed innovation. Therefore, it is worthwhile comparing the expressed aim with the actual use of the activities that should lead to this aim. The STTIS research teams are interested in knowing how teachers transform the innovations encountered and in seeking certain trends in the nature of these transformations. This knowledge could avoid a number of drawbacks with regard to an appropriate implementation.
This has been the main aim of the **Workpackage 4**.

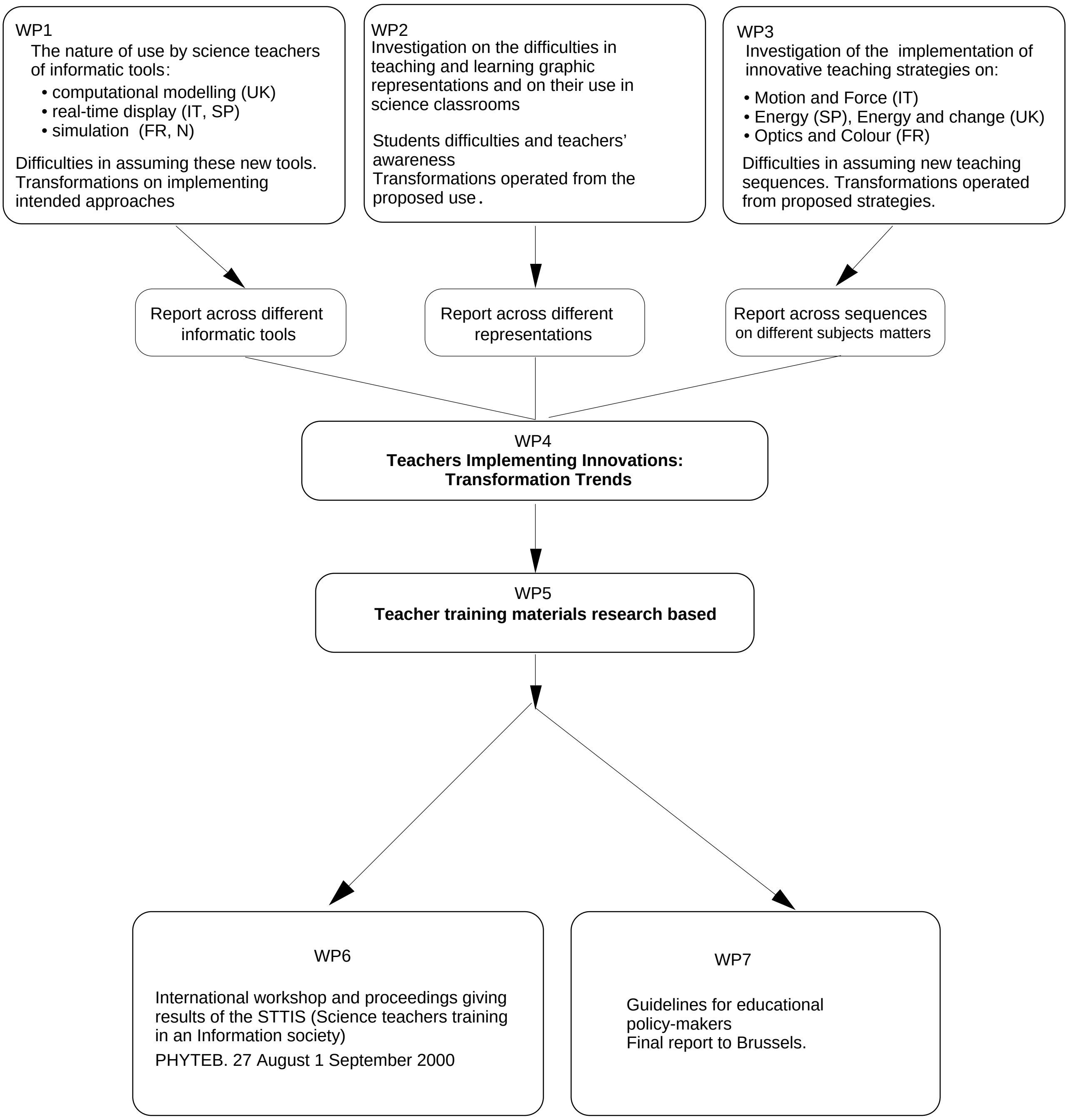
Teacher training activities mainly based on research results of the STTIS project have been designed/prepared to favour the take-up of innovations. The aim has been to increase awareness of factors which may foster better adaptation to innovations. They constitutes **Work package 5**.

The interaction with other researchers who have not been involved in the Project is an important element of the dissemination. That’s why it has been planned to organize symposia during European Science Education Research Association (ESERA) Conferences and to organize an international Conference in the ICPE and GIREP (Group International pour la Recherche sur l'Enseignement de la Physique) frame. This constitutes **Work package 6**

The extension and diffusion of the results of educational researches such as STTIS results is a very crucial point. Therefore we have summarized them and propose a set of recommendations and guidelines for policy-makers and teacher trainers. This summary constitutes **Work package 7**

The following schema gives a general vision of the tasks carried out in the frame of the STTIS project.

3.3. Summarising chart



4. Methodology

4.1. Nature of the research

The research methodology adopted is *qualitative* in nature, because we believe this to be the right way to address the essential problems in this case. As indicated below, quantitative methods might become appropriate at a later stage, after the qualitative diagnosis and description of the problems has been done. It is this first stage of diagnosis and description which the research in STTIS addresses.

The research is fundamentally *applied in character*. It is directed to informing and so to potentially improving practical decision-making and action. By 'informing' decision-making and action we do not (and could not) mean providing a base of data and theory from which decisions and action could be in some way completely derived. Such decisions and action in real time always have to go beyond available evidence. Instead, we mean providing data and interpretations which suggest priorities for action, indicate crucial factors which should be taken into account, and identify difficulties which action needs to overcome.

There are always two kinds of information relevant to practical action. They concern the two different questions of *existence* and of *prevalence*. For example, in the field of public health, it may be necessary to know both the nature of a problem (e.g. what is the disease?) and how extensive it is (how many have the disease?). It is important to note that the first question (existence) is logically prior to the second (prevalence). We cannot even enquire how widespread a problem is until we have diagnosed its nature.

To answer the second kind of question adequately requires large and carefully chosen samples. To provide useful answers to the first kind of question does not require large samples; instead it requires carefully cross-checked in-depth investigation. To use the previous analogy, one may only need a few cases to characterise a new disease, but one has to conduct extensive tests and investigations on those cases. One may also compare the way political parties use small 'focus-groups' of people to discover crucial aspects of the way policies are perceived.

Answers to the first kind of question (nature and existence) guide decisions in suggesting what should be done - the nature of the required action. Answers to the second kind of question (extent, prevalence) guide decisions as to the scale of the required action.

Broadly, the three researches (WP1, WP2, WP3) *address the question of the nature and origin of difficulties*, and only secondarily concern their prevalence. However, the design is such as to increase the likelihood that the problems which are found and characterised (diagnosed) will prove to be of general importance and significance; that is, that they are not trivial in nature and are not highly localised and specific, relevant only to a few contexts. In the given context (Science Teacher Training in the Information Society) this can be achieved by:

- parallel investigations in different European countries
- focusing on teachers who are willing to innovate.

The first - comparison of different European contexts - clearly helps to distinguish difficulties which are more, or are less, strongly related to local cultures and circumstances. The second is subtler. Much experience, in many countries, shows that although some difficulties for teachers in responding to innovations depend on (for example) inexperience, unwillingness or unfamiliarity, and so are not fundamental and are often transient, other more important difficulties are fundamental. That they are fundamental is indicated by the way they are present after 'transient' phenomena have died away. If willing and reasonably experienced teachers resist, or in transforming act to subvert, an innovation, we have reason to think that the problem is deep-rooted and may well appear in different circumstances. Thus it is a feature of the methodology to avoid studying transient effects, and to concentrate on those likely to appear when teachers are seriously trying to implement an innovation.

The methodology also has to take into account that education is a form of planned, purposive, *communal action mediated by agents (teachers).* Planners or legislators in education are obliged to act through teachers. Teachers have their own purposes and goals which may conflict with those planned. Teachers have their own understandings which may transform the understanding of the intended action. Teachers act under specific constraints (e.g. time, resources) which planned actions may not have taken into account. Thus it is necessary that the methodology provides for the investigation of plans and intentions, and of different understandings of - of different meanings given to - these plans and intentions. Further, the methodology, besides taking into account the intentions of teachers and other agents, has also to take into account the influence of the researchers themselves. It can never be enough to study teaching in action alone.

In using informatic tools designed by others (for example, Computer Based Laboratory, or Interactive Physics) we need to distinguish the innovative intentions of the particular uses of the tool which are investigated, and the general intentions of the tool designer, which are often embedded in the tool's functionalities and characteristics. To do so is not simple, because innovative proposals are often very much based on what can be done educationally with the tool as designed. However, the possibility of such a 'second order' difference in intentions needs to be borne in mind.

4.2. Cross-checking - 'triangulating'

Such investigations place a heavy demand on cross-checking - on 'triangulating' - data and interpretations of these data, from a variety of sources. What people say they do is not always what they can be seen to do. The reasons they give for actions are not always consistent with what the situation appears to demand. Interpretations of evidence necessarily owe something to the interests of the interpreter. Actions are not always consistent or coherent.

For this reason, we intend to rely on *multiple data sources*. Interviews with teachers give some data about purposes. Interviews before and after teaching can cross-check stated purposes against reasons for observed actions which may seem to have different purposes. Class observation can notice both how purposes are translated into action, and actions which appear to serve unstated (even opposed) purposes. Analysis of tasks teachers give students to do (e.g. questions they set) can give evidence of teachers' conceptions of desirable outcomes, and give concrete content to aims otherwise only stated in general (perhaps not very clear) terms.

It is essential to provide for, but also to control, variety in the specific contents and contexts of teaching which are studied. A type of disjunction which appears between (say) a teacher's own stated aims and that teacher's actual practice, in the case of more than one type of informatic tool, is more likely to be general and less likely to be a function of that specific tool. A kind of conflict which appears between the intentions of planners and the intentions of teachers, in the case of more than one area of science, gives grounds for expecting it to be found elsewhere.

We require, therefore -for example- controlled variety in the informatic tools investigated. Those chosen are:

- tools for simulation and modelling
- tools for acquiring and representing data

In the case of graphic representations, defining the nature and scope of this controlled variety is itself problematic. In advance of the research identifying difficulties in learning and using such representations, it is necessary to use some a-priori scheme for identifying problems of representation. It becomes part of the research to check whether this a-priori scheme appears to be well-founded. Thus triangulation helps to test the relevance of the evidence and analysis on which the data collection is based.

There is also the matter of cross-checking or triangulating the terms and concepts used in analysing data and forming hypotheses or interpretations. We have (of course) already found in comparing previous researches amongst members of the STTIS project, that questions of this kind immediately arise. Are results obtained by one group and described in one way essentially 'the same phenomenon' as those produced by another but described differently? Or, despite similarities, are they actually different in some important way? If different, is this a difference in outcome due to different national contexts, or is it a difference in the questions asked, in the problem addressed? We rely on triangulation, within and between national data, to provide ways to decide such questions at least tentatively.

Thus the methodology will provide for cross-comparison not only of 'results' but also of methods used and conceptualisations formed to 'produce' those results. Data from one country needs to be re-inspected using the interpretative schemes used by another country, for example. It must also provide for cross-comparison of methods of investigation, which may either detect robust phenomena which appear despite differences in method, or may detect phenomena which appear fundamental but are actually likely to be an artefact of method.

4.3. Opportunity sampling

Since the research is to be grounded in observation of actual classroom work and analysis of existing innovations and plans, it follows trivially that these have to exist in the different countries involved.

This produces immediately two difficulties which can at best be only partially resolved.

The first difficulty is that not every required kind of innovation exists in every country. For example, WP3 calls for planned, documented innovations, a model for which is the planned introduction of compulsory work in optics on a national scale in France. There is of course no chance that the same thing will have occurred in another country. It may be that the nearest thing in common is a local innovation done on a voluntary basis in a quite different topic - for example introducing ideas about teaching qualitative thermodynamics in the UK. This could hardly be called 'controlled variation', but we are obliged to accept it or do nothing. Similarly, in France we can study the teaching of geometrical optics using an informatic tool, but geometrical optics is not always compulsory in the curriculum in several other countries, and is absent in some. Equally, however, we can and will look for the maximum coincidence in curriculum content and kinds of innovation as between countries, even if in some they are 'official' and in some not.

A further constraint, with the same consequences, arises from the examples of innovation actually available to researchers in the various partner countries. We are obliged to select those cases for which an opportunity presents itself or can be created.

The second difficulty, arising from the first, is that variations between national cultures and between content, kind and context of innovations, are inevitably confounded (mixed). This is of course a feature of reality in trans-European action of every kind. National cultures, structures and practices themselves help to determine the nature of innovations which are practicable or are thought desirable. Thus innovation can not be 'held constant' whilst national culture and context vary. It follows that analysis must treat this as a real phenomenon rather than as a methodological flaw. Results purporting to be about a kind of innovation need to be set in their national context, hypotheses about the effects of that context being made explicit. The corresponding advantage of cross-national research is that features of the local context, often rather 'invisible' to the local eye which takes them for granted, are thrown into relief when that context has to be understood from a different national context. (The fact that a UK teacher can legally not be told how to teach a given topic, may assume greater significance when set against a country in which this is expected and accepted.)

4.4. Variations in research designs

At first sight it appears obvious that research designs should be the same in different countries conducting parallel investigations. In practice this will not always be appropriate or possible. A simple example is that in some countries it is necessary to begin an investigation with identifying a range of difficulties students have in a particular context, whereas in others such work has already been done and can be by-passed.

A more fundamental difficulty is that in some cases the methodological strategy needs to be varied for reasons of principle. For example, there is a real difference between how one has to investigate representations which are familiar to students and ones which are novel. In the first case a questionnaire can elicit difficulties encountered in several examples, but in the second case the novel representation itself has first to be established, which generally cannot be done through a simple questionnaire.

They key criterion to adopt, is that methodologies should vary only for principled reasons, and that different methodologies adopted do address the *same* overall questions. Thus in the above case, *in order that* an investigation of a novel representation addresses the same questions as an investigation of a familiar one, it is necessary to vary the procedure so as to make the two cases *more*, not less, comparable. In this way, we are confident that common results will be meaningful.

4.5. Towards a common language of analysis

It is likely that cross-nationally phenomena will be seen which if described in common terms seem similar, but if described in different terms seem different. Thus the question of how to describe results (terms in which results are reported) will be a fundamental and essential part of reaching a trans-national report.

This will have to be reached by putting separate national reports together and comparing them. But before the national reports are finalised it will be essential to discuss and compare initial forms of analysis, so that unnecessary differences in terms of description are minimised. To do that will require access not only to draft parts of reports but also to some representative data, so that the discussion is not purely about words but is also about words in relation to evidence.

In doing analysis of such data one necessarily creates analytical concepts/descriptions (e.g. "serial causal reasoning"). Email can be used to circulate ideas for such concepts as they begin to emerge, so that others may try looking at their data in that light.

The aim is not to force reports into a common language, but to agree about which of the phenomena we think we see are probably related, and how. It is likely that the level at which there is a real commonality is quite deep, beyond the point where the local context is important. Thus it may go beyond the surface of actual evidence available, and have to be hypothetical rather than factual.

4.6. Steps of the research

The above general methodological approach is adapted to the different steps of the STTIS research, varying as necessary according to the nature of the investigations but retaining overall unified coherence. In the next paragraphs, details are given of how it has been adapted to the three different phases and work packages.
The STTIS research plan contain 3 phases or stages:

4.6.1. Phase 1. Parallel empirical investigations about the implementation of innovations in five countries

The first phase of the STTIS research focused on three empirical investigations areas, each of them related to a type of educational innovation and being the theme of a work-package (WP1, WP2, WP3). It is the longest phase and essentially has consisted on the following tasks:

1st. Some curricular innovations are chosen in different domains relevant to today's society.
2nd. For all the chosen domains, each research team specifies and delimits the innovations in order to take into account their implementation and to carry out a specific plan of research, together with the design of data gathering tools.
3rd. Each research team chooses a sample of the corresponding country's teachers who are willing to implement these innovations in their courses.
4th. In-site data are collected in order to account for the way in which each innovation proposal has been implemented by teachers from each country.
Parallel different research for each of the curricular innovations can be carried out within each research team.
5th. Each research team gathers data from different sources (interviews, observations, documents). These data are put together for all the implemented innovations.
6th. An in-site analysis is then undertaken. As described by Denzin and Lincoln (1998 p 187), the in-site analysis follow an inductive path, looking for tactics for generating meaning by moving mainly from the concrete to noting general patterns and themes, asses *plausibility* (making initial, intuitive sense) and *clustering,* and looking for connections.

This phase is finished when all the studies research teams have been completed. In the STTIS Project, such reports correspond to the National Reports completed by all research teams with regard to each of the implemented curricular innovations

4.6.2. Phase 2: Crossing national results regarding a particular innovation

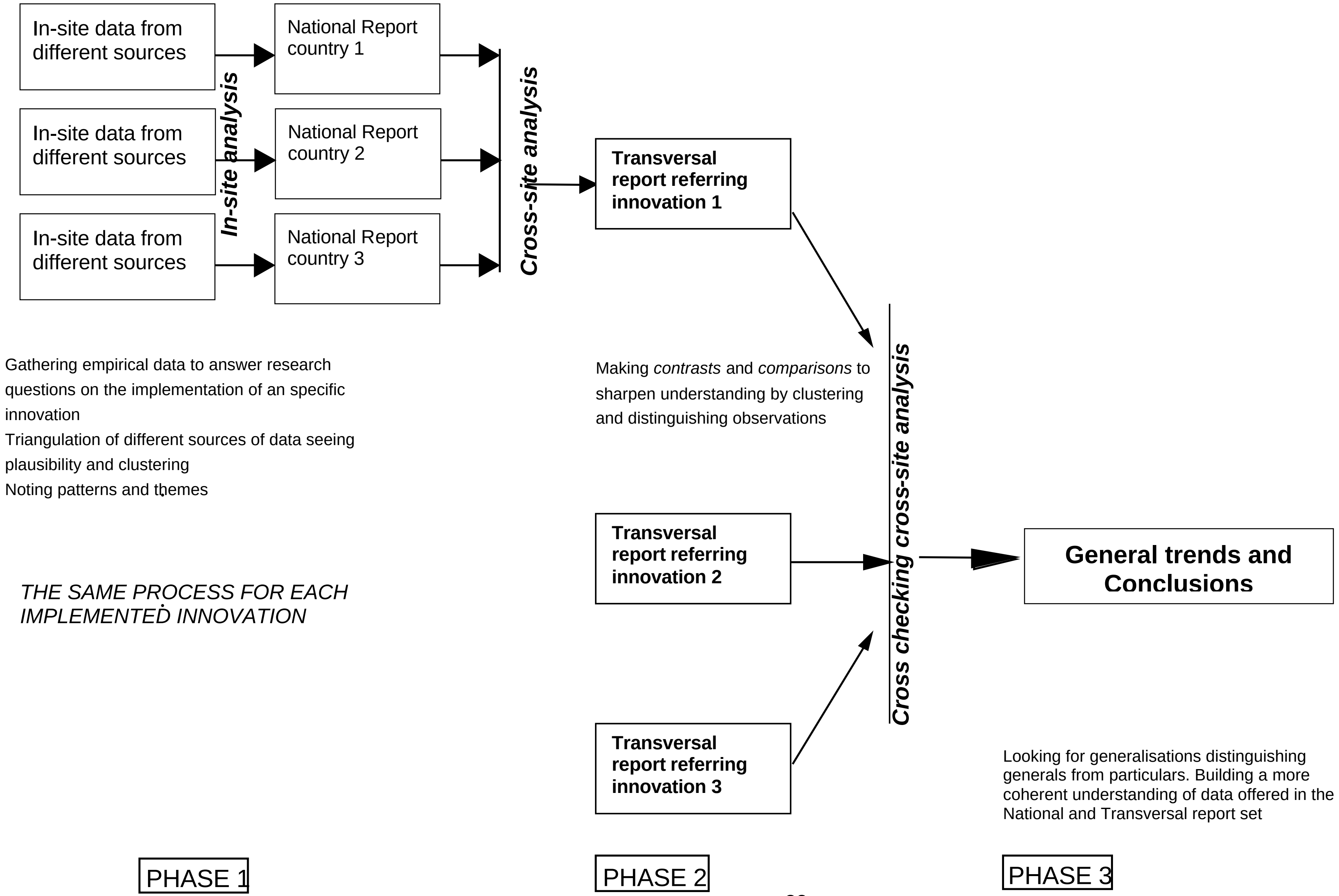
In the second phase, a cross-site analysis from the National Reports is made regarding *each implemented curricular innovation.*
The cross-site analysis is undertaken by *contrasts* and *comparisons*, as a strategy intended to sharpen understanding by clustering and distinguishing observations. This allows a Transversal Report for each of the selected domains to be attained. In the STTIS Project, a number of Transversal Reports related to every type of curricular innovations has been drawn up.

4.6.3. Phase 3: Crossing results on parallel innovations across countries

In the third stage, given the results from the Transversal Reports, a cross-checking from cross-site analysis is carried out. In this phase (again, according to the Denzin and Lincoln process steps), the work should follow more abstract tactics, distinguishing generals from particulars, shuttling back and forth (when convenient) between first level data and more general clusters, trying thereby to build a coherent understanding of the data sets. It constitutes the Work package 4.

Schema 1 graphically represents the layout of the different phases.

4.6.4. Schema 1 Layout of the different phases



RESULTS

PHASE 1 AND PHASE 2:

Parallel empirical investigations about the implementation of innovations in five European countries

and

Crossing national results regarding a particular innovation

The next pages describe now in some detail the work content of each of the work packages referred to the implementation of a selected innovation.

5. Work Package 1: The nature of use by science teachers of informatic tools

This chapter had been written on the basis of the transversal reports: *The State of Art in the Use and Value of Informatic Tools. RW1.1.* Stylianidou, F., Ogborn, J. and Contini, M., Gutierrez, R., Kolst¯, S. D., Ott., M., Perez, O., Pinto, R., Quale, A., Rebmann, G., Sassi, E., Viennot, L., 1999; and *The nature of use by science teachers of informatic tools*. RW1.2. Stylianidou, F., Ogborn, J. and Balzano, E., Giberti, G., Gutierrez, R., Kolst¯, S. D., Monroy, G., Pérez, O., Pintó, R., Quale, A., Rebmann, G., Sassi, E., Viennot, L., 2000, (http://blues.uab.es/~idmc42/document/index.html)

This workpackage WP1 is devoted to investigate transformations in taking up innovations designated as informatic tools. It has been articulated in two subworkpackages WP1.1 and WP1.2

5.1. State of the art on the use and value of informatic tools (WP1.1)

The Annex*: STTIS WP 1.1. Report: The State of the Art in the Use and Value of Informatic Tools* (http://www.blues.uab.es/~idmc42) contains all the results

The state of the art on the use and value of informatic tools in the five partner countries (France, Italy, Norway, Spain and the UK) were examined.

The study was concerned with the provision of and kinds of use of computers and informatic tools in secondary schools and more particularly in science and technology classes. As planned, the report is based mainly on existing national or regional data from about 1990. However, where such data did not exist or was limited, it has proved possible with STTIS to supplement them with specially conducted surveys (see Italy and Spain).

It also provides an annotated review of the most important research or survey papers which have appeared in the scientific or educational journals of each country in relation to the above topic, in the recent years (i.e. 1995 onwards). Earlier papers have been included if they were of special importance. Priority has been given to papers on themes most relevant to STTIS, namely:

- computational modelling tools;
- simulation software; and
- real-time experiments and display tools (excluding Internet).

The report Annexed (STTIS WP 1.1. Report: The State of the Art in the Use and Value of Informatic Tools (http://www.blues.uab.es/~idmc42) contains the results. It has been divided into three main parts. In the first part, the provision of computers in secondary education is examined country by country; issues such as availability, location and access, cost of maintenance and replacement of computers are discussed. In the second part, the uses of information technology in secondary schools and more particularly in science and technology classes are discussed; issues such as use of specialised versus generic kinds of software (i.e. word processing, spreadsheet, database and communication tools) for teaching, contribution of information technology to teaching and learning, and teachers' competence and training in IT are raised. Finally, the third part contains a list of references of important relevant publications; for some of these publications a brief summary of the main points and conclusions is also included.

The discussion at the end of the two first parts of the report attempts a brief synthesis of the issues previously mentioned including some comparisons of the provision and use of informatic tools in secondary schools among the partner countries. Furthermore, through these comparisons, tentative as they are, some possible areas for future research at a European scale are identified and suggested.

Finally, the report as a whole sets the framework in which the data collected as part of Work Package 1 should be understood and interpreted, as it gives a state of the art account of the conditions science teachers encounter in their effort to implement the informatic tools that interest STTIS.

5.2. The current use of informatic tools (in 1998)

In all countries surveyed the use of generic software seems to prevail. More particularly, word processing packages were said to be used more than any other software package; spreadsheet packages come second and the rest follow. Specific software applications are used in specific study areas.

MBL and simulations are used strongly by some of the teachers but have not yet found a general use. Moreover, modelling remains a minority affair, despite some very strong arguments about its importance. Overall, in most of the countries for which we have data, the levels of computer use in science seem to be quite low compared with those in mathematics and language studies. Italy seems to differ in this respect.

The main factors that influence the use of computers in schools are identified, where we have data, by the teachers themselves to be the provision of relevant equipment and finance. These claims seem to be supported by the calculations and data of the previous part of our report. When prompted, teachers also identified training as an issue.

Consistently with the last remark, the impression we gained was that knowledge and experience with computers are spread thinly among teachers; in the best case a lot of teachers have little knowledge and experience with them, but not very many have a lot. Indeed, we might have anticipated that differences in provision identified in the previous part of the report would likely entail differences in numbers of teachers with substantial experience. However, we do not have enough evidence to make this claim.

The most important, though obvious, feature in all countries is the rapidity of change. Numbers of and use of computers alter by factors of more than two in only a few years.

The next most evident feature, given the rapid process of change, is the uncertainty about computing having found an integral place in education. That necessarily takes time. Similarly, there are large variations in the experience and knowledge of teachers, going beyond a first acquaintance with computers.

There are real and substantial differences between the countries in actual provision of computers (perhaps a factor of 5 between ‘best’ and ‘worst’ cases). But in all the countries there are policies established to develop computing in schools.

5.3. The use of selected informatic tools in the science classes (WP1.2)

The WP1.2 research focuses on the use of selected informatic tools in the science classroom. The aim has been to study how teachers transform expected uses of such tools and from this study to conjecture about difficulties and opportunities for the use of the tools in the classroom.
As stated, the informatic tools selected to be of interest to STTIS are basically of two kinds:

- computational modelling and simulation; and
- real time experiments and display systems.

The choice of these tools was informed by several reasons, among them:

- the important role which they are deemed to play in science education;
- that many teacher training programs address them;
- that their educational use has been endorsed by several relevant national and EU initiatives.

More particularly, the investigations of the use of these tools vary between partner countries as follows:

- France: simulation tools in teaching optics; and MBL (Micro-computer Based Laboratory) in mechanics
- Italy: MBL in teaching kinematics and forces
- Spain: MBL in teaching energy and kinematics
- Norway: spreadsheets and other simulation tools in teaching motion in force fields; CBL and MBL in teaching thermodynamics, mechanics and electromagnetism
- UK: spreadsheets and other modelling tools in teaching science

Case studies

In accordance to the methodology of Work Package 1 (STTIS 1998a), the above investigations were carried out as case studies of teachers using the tools in the science classroom (see Table 1 for number of teacher case studies per country). Teachers were selected by their willingness to participate and to attempt to make serious use of the tools.

Research questions

The case studies were concerned to identify possible factors which favour or hinder the take-up of the selected informatic tools in science classes, and to investigate how teachers incorporate these tools in the curriculum.

The main questions the case studies address are:

1. *What are the fits (matches) or gaps (mismatches) between the intended or expected use of the tools and the way the teachers actually use them in practice?*
2. *What do teachers identify as more successful and less successful examples of uses of the tools, and what reasons do they have for identifying them as such?*
3. *Are teachers conscious of transforming suggested uses of tools in their own practice, and if so what reasons do they give? If not, are there clues about what may determine the teacher's practice?*

Country	Informatic Tool(s)	No of case studies	Data collected
Italy	MBL in Kinematics and/or Forces	10	teacher interviews before class observations; class observations; informal teacher interviews after class observations; some informal student interviews
Spain	MBL in Energy and Kinematics	8	some teacher interviews before class observations; class observations; video recordings of some lab sessions; some teacher interviews after class observations; copies of worksheets given to pupils
France	MBL in Mechanics Simulation in Optics	7	extensive teacher interviews
Norway	Simulations of motion in external force fields CBL and MBL in Physics	10	statements of teachers' intentions; class observations; teacher interviews after class observations; copies of tasks given to pupils; copies of written work done by pupils
UK	Spreadsheets and other modelling tools in teaching Physics	8	teacher interviews before class observations; class observations; teacher interviews after class observations; copies of tasks given to pupils; some copies of written work done by pupils

In the above table one can see that teacher interviews were conducted in all the cases; these interviews differed in wording and duration but always explicitly asked for teachers' opinions about the intended aims and mode of use of the tools.

Conduct of case studies

The principle of triangulation indicated collecting a variety of data for each case. The specific kinds of data that were collected by each country can be seen in Table 1; in all cases they consisted of a practicable and appropriate selection from:

- observation records (researcher notebook) in the classroom
- video recording of student activities (if permitted or suited to the situation)
- recording (audio or video) of teachers' explanations
- copies of tasks given to students (worksheets, tests)
- copies of written work done by students
- interviews with teachers
- discussions/interviews with students

In the analyses of classes, it has been taken into account that the intended aims and use of tools will not necessarily be clear, or unique:

- that there may be competing ideas about the aims and use of a tool;
- that such aims and intended modes of use may be expressed in general terms which require interpretation by the teacher.

5.4. Crossing national results for WP1.2

This chapter had been written on the basis of the transversal report: *The nature of use by science teachers of informatic tools*. RW1.2. Stylianidou, F., Ogborn, J. and Balzano, E., Giberti, G., Gutierrez, R., Kolst¯, S. D., Monroy, G., Pérez, O., Pintó, R., Quale, A., Rebmann, G., Sassi, E., Viennot, L., 2000, (http://blues.uab.es/~idmc42/document/index.html)

5.4.1. Common conclusions across countries about the use of informatic tools on Science classes

The set of case studies, from five European countries, together provide a resource one can draw upon to suggest hypotheses and conclusions which may be common to, or relevant to, experience across more than one country. Reading the case studies as a whole, we are struck by the way, despite certain obvious national differences, it would be in general rather easy to imagine any one case study as having arisen in a different country. The issues which teachers face in constructing viable classroom events ('lessons') have much in common. This appears even though the schools range from difficult and disadvantaged schools to select and advantaged schools; even though teachers' circumstances vary from considerable expertise to relative lack of expertise; despite variations in the supply and availability of informatic tools, despite differences in teaching traditions and practices, and even though national school structures vary considerably.
For these reasons we are encouraged to suggest some tentative generalisations across these data, which may have useful trans-national policy and training implications.

5.4.2. Informatic tools are not fully 'naturalised'

Although in everyday commerce the use of computers in business has become more or less routine, it is not the case that in any of the countries, informatic tools have become an 'obvious' or 'natural' and 'taken for granted' tool for science teachers to use. This fact is reflected in the special arrangements which needed to be made, in all participating countries, to identify teachers to take part in the case studies. This was the case despite wide variations in the supply of computers (see RW1.1 STTIS, 1998b), in which Norway, UK and France have relatively good supplies of computing resources as compared with Italy and Spain. In Norway, with a high level of provision, and central Government insistence on the importance of computing in education, many Norwegian teachers nevertheless do not make much use of computers. The incentive of being provided with specially developed software and training in its use helped to find teachers willing to participate. In the UK and France, considerable efforts had to be made to identify teachers who were spontaneously making use of informatic tools in teaching science. Yet in both countries national policies and educational pressures exist to encourage their use. In Spain and in Italy, teachers whose use of informatic tools could be studied were identified by organising local development projects building on existing work, and providing considerable curriculum support, and sometimes loans of equipment. In summary, teachers using informatic tools regularly in teaching were the exception rather than the rule.

These facts are reflected in the fact that in each set of national case studies, there are teachers who are new, or almost new, to the tools they are using. And in many instances, the individual case studies reflect the teachers' sense of doing something new, of moving into uncharted territory. Those with considerable experience frequently mention their colleagues who have much less experience, and the – for them – relative newness of their own sense of expertise. Many refer to the novelty of the experience for students, whilst often also acknowledging that the use of computers is something students are likely to expect. Even where students prove competent in using computer applications (for example Excel), or have been given systematic training in their use outside the science classroom, science teachers generally regard this as a relatively new achievement.

One consequence of doing something new is that things often get worse before they get better. Mistakes are inevitable; ideas have to be refined and revised. This is nothing other than the well-known *'U-shaped learning curve'*. The case studies, in all the countries, reveal teachers generally aware of this difficulty, and often nervous of it. A few are sufficiently confident to expect to recover from problems encountered; more spend much effort trying to avoid foreseeable problems; some produce lessons which seriously disappoint them or an observer. On many occasions, what the teachers choose to do is open to criticism, which they themselves can often provide. At the same time, there are several case studies showing teachers rather rapidly achieving greater mastery of a tool, in the space of only a few lessons. And there are many examples of teachers reflecting on "How I will do it differently another time", showing an active involvement in turning their learning curve upwards.

Set against these simple and obvious facts is the rhetoric often associated with the use of informatic tools: that machine-based-laboratory work can develop physical insight and analytical ability; that simulation can reveal the essence of a process; that computational modelling provides new insights into the working of physical theory. Teachers by no means reject these kinds of claims, indeed they repeat them when justifying what they are doing (though a number are more sceptical). But the case studies rather uniformly show such large ambitions hindered by what may look like mundane difficulties, but which are often the actual consequences of using a given tool, as it happens to be, in particular circumstances. The arbitrary use of dollar signs in Excel addresses; the decisions made by programmers about the precision with which to display results; the way conceptual entities are represented in simulations; the sensitivity of sensors, are all examples of these practical realities which can impinge seriously on other goals. Real computer software and hardware inevitably comes with its own peculiarities, which 'text-book' science treats as completely inessential. And computers (on the whole unlike teachers) are prone to malfunction and to accident (such as being locked away).

The fundamental fact that many teachers using informatic tools are doing so without much experience to go on, and sometimes for the first time, necessarily colours any conclusions we can offer. We have found ourselves investigating a dynamic phenomenon, in continual process of change. The consequence is that we can make suggestions about what may initiate or help initially to sustain the use of informatic tools. We can say rather little about how the use of such tools might appear when (and if) they become habitual, that is, fully naturalised within the system. And we note that the continual rapid state of development of the informatic tools themselves means that this situation must be expected to persist.

Finally, the *newness or novelty of the use of informatic tools is widely given a value of its own*. In particular, teachers expect it to motivate students, to provide variety, to simply attract attention, to be "what the students want nowadays".

5.4.3. Dimensions of ‘distance’ or ‘lack of fit’

In all the case studies, the teachers are clearly conscious of the extent to which their work with informatic tools is or is not a good fit to what they believe they ought to be doing, to what they are accustomed to doing, and to what they feel obliged to do.

5.5. Teacher transformations related to the use of computer Tools in science classes (WP1.2)

According to the data provided by the five National Reports (WP1.2) and the Transversal Report (RW1), teacher transformations should be gathered whilst bearing two aspects in mind:

- teacher adaptation in order to use Computer Tools in their science classes.
- transformation of the use of IT tools expected by teachers in their science classes.

5.5.1. Teacher adaptation in order to use the Computer Tools in their science courses

The use of IT tools in science courses presents teachers, and sometimes the school, with a new situation. If teachers assume the use of these new tools, they then should try to:
- Practise the tools in order to acquire expertise in their use. Taking into account teachers’ general lack of experience in the use of IT tools, at stake are both the efficiency of the IT tools used, and the time that has to be invested in their effective use.
- Integrate the Computer Tools in the teaching process. Teachers may even, perhaps, plan a sequence of lessons containing the use of different Computer Tools in several steps.
- Plan the teaching sequence in order to get access to the computer-room when required (or use portable computers instead). A certain lack of adequate planning may have negative effects on the rhythm and timing of the teaching sequence.
- Invest the time allowed for Computer Tool use in a reasonable way, bearing in mind the pressure of time with regard to meeting syllabus requirements.
- Select phenomena appropriate for analysis through the IT tools; have well thought out criteria in order to reject the assessment of those phenomena deemed not worthwhile.

In short, the teachers’ adaptation of Computer Tool use in the science courses would benefit from increased flexibility in the use of different educational resources, and in their management of space and time.

5.5.2. Teacher transformations of the expected use of Computer Tools in science courses

According to the results, the implementation of IT entails a number of transformations or changes in expected use as an educational tool. Computer Tools used by teachers participating in the research have been designed along certain specific educational guidelines. Alternatively, there are general tools that can be used in specific ways. Without referring here to the reasons underlying such modification, we can describe the observed changes undertaken by teachers as follows:

5.5.2.1. Changes in the goals of proposed activities

There are examples showing that some of the teachers:
- Rather than using computer tools to help students learn scientific concepts use Computer Tools to learn how the tools themselves work, taking advantage of knowledge of a scientific concept.
- In preference to a running modelling favouring the structuring of knowledge of physics, the Computer Tool is used to describe a physical phenomenon by means of a model (already in the computer).
- Instead of asking students about the analysis of graphical representations of the evolution of a physical phenomenon, they ask about geometrical descriptions of graphical lines, and therefore the specialised (i.e. physical) meaning is dismissed.

- Rather than using a given computer tool to analyse a physical phenomenon, they use it to teach how a PC works, or to teach mathematics
- As opposed to using MBL to analyse real phenomena, they force the graphs to resemble ideal situations and interpret the irregularities as “lack of accuracy”.
- Rather than reporting on the unexpected lines of a graph with regard to a real phenomenon, it is explained in terms of errors attributable to the computer set or software. That is, teachers do not show graph differences linked to mathematical functions or graph differences linked to the evolution of a given real phenomenon.
- Instead of using MBL to show the graph being traced when a given phenomenon occurs, teachers arrange the equipment in such a way that does not guarantee all students having equal visual access to the screen.
- Rather than taking advantage of the chances of modifying settings related to graphical representation, teachers ask students to draw a single graph related to a given phenomenon. That is, teachers do not promote the analysis of what is permanent and what is variable in a graph (i.e. changing scales, zooming, etc.).
- In preference to taking advantage of the extra lab-work time to discuss graphs and data, timetables prevail.

5.5.2.2. Changes in the approach of tasks carried out during teaching

When the chosen IT tool has been designed according to specific ways for practising certain tasks, it would appear that the approach to some of these tasks has been changed, as in the following examples:
- Exercises designed to focus on unknown answers, assigning values to variables, can be converted into exercises that look for values relevant to certain answers.
- Exercises designed to analyse experimental data and graphs can be converted into exercises directed towards handling computer equipment, with no analysis of the results whatsoever.
- Tasks designed to build a model are converted into tasks for running a model.
- Tasks designed to work with the computer are converted into homework tasks to complete a worksheet.
- The use of a simulation tool in guided and free ways is converted into the use of CBL or MBL in order to establish better efficiency control.
- Questions raised in order to promote student discussions are converted into rhetorical questions answered by teachers themselves.
- The use of spreadsheets that require extra computer programming work is converted into the use of dedicated software, regardless of the fact that this is less evident to students.

5.5.2.3. Changes in cognitive demands made to the students

Several instances could be interpreted as a tendency to change cognitive demands originally planned in the curricular innovation:
- Rather than being concerned with students’ construction of a mental model of a computer set, teachers give instructions on what should be done step by step, without providing a general idea of tool constituents and how they work.
- ?Instead of enabling students to comprehend a concept or related group of concepts, teachers introduce concepts without relating them to each other.
- In preference to taking advantage of unexpected graphs (on screen) as a means of provoking cognitive conflict, teachers repeat graphs or sometimes even provide the "right" choice
- Rather than promoting the internalisation of the goals as a way of favouring self-regulation, the intended teaching activities turn out to be simply 'motivation tasks'
- As opposed to trying to elicit previous concepts, the corresponding teaching episodes consist of answering simple questions.
- Instead of promoting concept structure, problems are seen as challenges from which pupils and teacher can learn.

5.5.2.4. Changes in the degree of student involvement

It has often been observed that students turn out to be passive subjects insofar as they merely look at the teacher working with the computer.
A different situation has also been observed: teachers do not show their students how to deal with the computer. Rather, this job is passed on to skilful advanced students who, in turn, show provide their classmates with the information in question.

5.5.2.5. Changes in the expected use of Computer Tools in order to comply more adequately with teachers' conditions.

It has also been observed that. Only those aspects directly related to the teacher's routines are selected. In other words, the computer's only use is to be the servant of the usual.

5.5.3. Factors that may influence teacher transformations

5.5.3.1. The relation with the accepted subject contents

The teacher's perception of the degree to which a proposed use of a computer tool 'fits' (that is, is not too distant from) certain accepted segments of required content knowledge in the subject (we are mainly concerned here with physics), is critical to its acceptance.
If the fit is not acceptable, use of the tool will be transformed in order to make the fit better. The computer tool is easier to accept when the 'distance' between its use and existing syllabus knowledge is not great.
Where the proposed use of the tool carries with it new subject matter, which is too distant from that which the teacher expects, both the use of the tool and the new subject matter are likely to be transformed.

Overall, teachers do not regard the specific use of the computer as a 'subject matter to be learned' in itself, but generally as a means of helping students to learn of something else. That is, in some respects, it is a kind of transformation. A tool with new learning and teaching potential is confined to the role of reflecting what is 'usual'.
On the other hand, it is also the case that several successful 'curriculum packages', such those involving work with MBL, have put together new tools, content and practice in a convincing way.

5.5.3.2. Teachers' convictions and beliefs about what they ought to be doing

Most teachers have strong convictions and beliefs about the value of computer tools, about the role they should play in teaching, and about the way they can facilitate learning and engage students. Any proposal concerning the use of computer tools is likely to be met with objections on the grounds of some conviction or other; these objections must be overcome if the proposal is to succeed.
Some characteristic beliefs are:

Convictions about the need to master use of computers

These range from believing that teaching students how to use an computer tool is central to studying science, to believing that such activity is a necessary task for which the school must plan in advance. No teacher doubted the teaching investment that needed to be made, but they differed in their view of who should be making such investment.

5.5.3.3. Convictions about goals for students

Differences in teachers' beliefs about their own roles, and about what is important for learning, led them to emphasise differing qualities to computer tools: on the one hand, involvement and activity; and on the other hand, efficiency and the demands placed on students' reasoning.

Convictions about efficiency

Teachers claim that computer tools can, or should, save time, do things more efficiently, or do things faster or in greater quantity. However, the idea that the use of computer tools in teaching subtracts from total teaching time does not appear to survive experience of using them. Teachers are often struck by how much time is needed to discuss results, trace errors in a model and manage equipment. There is also the phenomenon that, by adding to what can be done, the computer is liable to add to what apparently needs to be done.

On the other hand, the use of a computer tool often shifts the focus of work rather than adding to it. For example, MBL makes collecting and processing large amounts of information very efficient, thereby shifting the focus of work onto the arguably more important and valuable tasks of analysing, interpreting and discussing the data collected. The teacher does, of course, have to share this conviction about priorities.

Generally, tools which are not seen as delivering sufficient value, or that take too long to do so, will be rejected. Tools which offer something unique but important, and do so without taking too much time, stand a better chance of acceptance.

5.5.3.4. Convictions about precision and correctness

The consequences of the fact that computers generally produce definite, clear-cut and often well-presented results are not seen in the same way by all teachers. Some value the way computer use may circumvent student errors: giving the 'right' graph or the 'correct' ray diagram, for example. Others are concerned that students will too easily believe the computer, and take opportunities (such as the failure of certain integration algorithms) to stress that clear-cut result can be wrong.

This difference is related to differences in teachers' convictions regarding the nature of science, as well as the nature of teaching and learning.

5.5.3.5. Teachers' customary or habitual practices, and those expected of them

There can be little doubt that 'old habits die hard'. Essentially every case study shows a teacher trying to achieve a balance between the use of the computer, and habitual classroom practices with which that teacher and class are familiar. Some innovations seem to work by providing a fit of this kind, which is one that feels comfortable to a wide range of teachers (though by no means to all).

A common transformation of intentions is to select only those aspects of the proposed teaching sequence that fit customary practice.

Customary roles of teacher and student

Differences in the use that teachers make of a computer tool are often related to teacher convictions about appropriate student goals, and to the type of personal relationship that they want to establish with students.

However, what is also important here is the flexibility and skill with which different roles are managed and varied, since a shift towards learner-centred computer use is favoured by openness to changes in the role of teacher and learner.

5.5.3.6. Practices in relating theory and experiment

Teachers in all the countries studied were conscious of the need to decide on the sequencing of practical experience and work with the computer. This sequencing is often related to practice that is additionally related to teacher convictions regarding the primacy of theory or experiment, and sometimes (but not rigidly) related to a national culture.

5.5.3.7. Integration of computer tools into the teaching process

‘One-off’ uses of computer tools are sometimes jeopardised by unanticipated difficulties, especially those connected with student and (often) teachers’ lack of familiarity with the tool in question. At the same time, how else is a teacher to get started on using a new tool?

In other cases, the use of a computer tool is integrated within a lesson sequence planned by the teacher, and in certain cases, within the use made of computer tools elsewhere in the school. It is striking, for instance, how the successful use of a computer tool sometimes depends on it having been practised with at other times. Where these conditions are not met, the aims of a lesson can be put at risk.

Within a single lesson, some teachers (often rather experienced ones), integrate the use of computer tools with other activities, within an overall guiding plan.

In addition, many teachers see it as necessary to integrate the use of computer tools into a coherent sequence of teaching across several lessons. The tools can be used in very different ways to do this, however. A tool may be used to summarise or review previous work; it may be used to introduce new work; it may be used several times as ideas are developed and harder problems are tackled, for example in Newtonian dynamics. Or different tools (for example simulation and data analysis) may be used in co-ordination.

5.5.3.8. Space, time and resources

Practice in the use of computer tools is significantly shaped by what resources are available, by where they are located, by when they are available and by who has charge of them.

Each lesson has necessarily to adapt to this practical environment. A very common pattern, in all the countries studied, is to concentrate computing resources in a central bookable suite (or suites). This means that their use and integration into other activities has to be pre-planned. Practice that requires informal spontaneous use does not then develop, except where students have computers at home.

Teaching curriculum and examinations

Teachers see computer tools as competing for time with other essential aspects of the curriculum. Time pressure is a crucial factor in the take up of these tools. The nature of examinations is particularly critical in determining what teachers feel they must find time for. Policy makers need to recognise that it is not enough simply to insist on the importance of using computer tools, if nothing is done to modify the existing teaching programme and examinations.

5.5.3.9. Practices involving colleague teachers

Relatively few case studies report significant interaction with other teaching colleagues. Rather, the picture at present is that mainly of individuals developing their own ways of using computer tools.

This said, the policy of the school regarding systematic teaching and provision of computer tools is very important. Successful use was very much facilitated in several case studies by frequent and customary use of certain tools by students. These are likely to be either generic tools (such as a spreadsheet) or standard tools provided in the school for a range of classes (for example REGRESSI in France).

6. Workpackage 2: Investigation on the difficulties in teaching and learning graphic representations and on their use in science classrooms

This chapter had been written on the basis of the transversal report: *Investigation on the difficulties in teaching and learning graphic representations and on their use in science classrooms*. RW2. Pintó, R., Ametller, J., & F. Chauvet, P. Colin, G. Giberti, G. Monroy, J. Ogborn, F. Ormerod, E. Sassi, F. Stylianidou, I. Testa, L. Viennot, 2000.

6.1. General view of the research studies carried out on graphic representations

The use of new technologies has made available an increasing number of images used in communication due to their efficiency in transmitting information in a fast and compact way. These technologies have also increased the typology of visual communication and the possibilities of creating new images and of manipulating them. Therefore, the information society is creating a culture in which images acquire a higher profile as a way of communication.
In science teaching as well in all the media presentations, the use of symbolic languages is more and more usual. Sciences classes, since the use of symbolic language is frequent in Science, are the most common places where students learn to interpret and construct graphs and different symbolic representations.
The Gestalt theory of perception has still influence in the teacher's minds and the use of drawings, pictures, graphs of all kinds seems to assure the success of learning. Always it is accepted that the use of the symbolic representations helps the understanding of underlying concepts or ideas, this assertion needs to be evidenced. Understanding the reasons why an specific image is included or used for a specific concept requires knowledge coming from different fields: from communication and semiotic theories and from scientific disciplines.

There is a long and distinguished history of theorising about the nature of graphic communication, often starting from perspectives in Art or in Sociology. Some relevant empirical work concerns difficulties in constructing and reading graphics intended to communicate scientific information (example, Cleveland 1985, Tufte 1983).

An starting point of the research has been to consider images as useful tools to help communicating and understanding concepts, processes, interrelations, etc. (Kress and van Leeuwen 1996) and, thus, they cannot be relegated to the role of mere illustrations of a verbal text that is transmitting the essential ideas. In our research the theoretical perspective of Kress and van Leeuwen (1996), which was used already in investigations of visual communication in science textbooks (Ogborn, Kress et al) has been an agreed point to supplement the scientific content criteria for selecting images which potentially present problems for students and teachers.
An a-priori inspection of images in science texts certainly suggests that students' and teachers' conceptual difficulties in science are reflected in images which are used, and indeed that some images may create new difficulties. Our purpose was therefore to work on innovative teaching materials so as to detect possible transformations in the use of images, including images generated by informatic tools.

Briefly, our research has tried to uncover some possible repercussions of the new scenario in the use of images in the science classes. Do students have difficulty in reading images? Are teachers able to interpret students' misunderstandings of images? Is the grammar of the visual language transparent to our students? In particular, our study has focused on the ease or difficulty of communication through the use of images with students aged 12 to 18 years.

6.2 Programme of research

Research questions
To carry out these aspects implies answering the following questions:

1. *What are some of the problems and opportunities of the use of graphic representations in science classrooms that can be anticipated on grounds of prior evidence and/or theory?*
2. *Are these confirmed by students' readings of such representations?*
3. *How do teachers understand the anticipated problems?*
4. *How do they deal with such problems, in the context of innovative teaching involving the use of images and graphic representations?*
5. *What transforming mechanisms can one conjecture to be involved*

The research has been designed to make comparable the design and the methodology followed across the four teams. This was done:

- In order to be able to distinguish between difficulties which are more or less strongly related to local cultures and circumstances, and difficulties that are common.
- To make meaningful cross-comparisons of a controlled variety of specific images and contexts. Studying different images under different circumstances (different countries, different schooling levels, etc.), but from the same point of view and frame, turns the common results into more reasonably generalised ones.
- To provide a common frame to analyse students' difficulties. (See the section list of textual/graphical features of images below.)
- To use similar procedures for collecting data: interviews with students before and after being taught, written questionnaires and interviews with teachers about students' answers, etc.

Selection of images

The selection of common features to analyse the images used inside the STTIS consortium has allowed a homogenisation of the results coming from the different teams involved in the project, and thus, their possible comparison.
The images used by the different research teams can be characterised from two different points of view:

- According to the degree of graphical innovation they imply
- According to their graphical characteristics

Research team	**Type of images**	**Modality**[2]
Université Denis-Diderot Paris VII. France	Representative images of common textbooks (on optics for secondary school) whose design seems to present difficulties to students.	Scientific Modality
Universita Federico II of Napoli. Italy	Documents containing graphs representing data collected in real-time experiments (of motion and force) and thus connected to the use of informatic tools.	Scientific Modality.
Universitat Autònoma de Barcelona. Spain	New images designed to represent scientific concepts (related to energy) that are not commonly graphically represented.	*Mainly two modalities: naturalistic and technical.*
University of Sussex. UK	Typical images of lower secondary science textbooks (on energy).	Mainly two modalities: naturalistic and technical.

[2] The term modality comes from linguistics and refers to the representation of the truth-value or credibility of statements about the world. Each community establish some textual/graphical clues that guide them to decide if a particular image is a reliable representation of the world or not. I.e., the community of scientists have established different modality markers than the community of advertisers, community of artists, ...

As can be seen, the different kinds of images used by the four teams have characteristics that make them complementary, to form a representative set of usual or expected images in science courses. On the other hand, studying different images under different circumstances (different countries, different schooling levels, etc.) but from the same point of view, turns the common results of our different analysis into more reasonably generalised ones. The common difficulties found in this set of images provide good grounds to think about general problems in the reading of images beyond the specific scientific subject represented by the image or the particular selected image itself.

List of textual/graphical features of images

The research framework in which the research teams operated identified a list of textual/graphical features of images which may present difficulties for students when reading and/or interpreting documents[3] containing images. The ones relevant to the papers presented here are:

a) Images requiring interpretation of the roles of elements representing both real world and schematic or symbolic entities. *(R/S)*
b) Images constituting on-screen graphs, representing data being collected in real-time experiments, where external observable processes and graphic representations need to be related to one another. *(RT)*
c) Images whose interpretation requires to give importance or highlight certain elements, often in relation to textual/graphical features which makes them salient, or do not make them salient. *(SEL)*
d) Documents with images requiring different conventional scientific representations of the same concept to be read: representations may be mixed or have the same concept represented differently. *(MIX)*
e) Images containing elements which require appropriate readings of symbols, and which contain examples of synonymy, homonymy and/or polysemy of symbols. *(SIM)*
f) Documents with images requiring verbal elements to be read as an important part of the whole, containing verbal elements included in the image or used as captions. *(VE)*
g) Images that make important use of compositional structures and require the reading of spatial distributions and different representational structures. *(CS)*
h) Documents containing more than one image requiring an interpretation of the relationships between the different images. *(INT)*

Three research studies constitute the work in the Work package 2, articulated as subwork packages WP2.1, WP2.2 and WP2.3

6.3. Students' difficulties in reading images (WP 2.1)

Since we consider that images are not trivially understandable it is necessary to know which are the features of images that may imply difficulties on interpreting them. The first part of the investigation is focused on the study on the students' difficulties when reading images.

A set of images and graphics (including computer displays and function graphs) has been selected according to criteria which make them *a-priori* 'interesting' for the research. To be 'interesting' an image or graphic should show some feature which relates to known difficulties students have in understanding the topic in question or in reading graphic displays of a particular type proper to the topic. The image or graphic may be 'interesting' either if it is open to the danger of creating or reinforcing a misunderstanding, or if its design suggests that it might combat or overcome such a mis-reading.

Data were provided on how students do in fact read such visual materials, taken either from specially designed research tasks or from observation of their working with the materials in the classroom (or at the computer).

[3] The word 'document' is used in this report to refer to the combination of text and images on a page.

Crossing national reports about students difficulties in reading images (Summary of WP2.1 results)

6.3.1. General trends of interpreting images detected in students' readings

6.3.1.1. Pre-eminence of narrative readings

Tendency to make narrative readings of the images, i.e. to interpret them as if they had a story-like structure. Students seem to give excessive relevance to elements related to this idea such as arrows and common compositional structures (left to right arrangement, ...). As a consequence, "time" is present in many of the students' explanations.

6.3.1.2. Misreading when information is missing

When facing documents that do not include the information necessary to correctly interpret them, students often resort to interpreting mechanisms that can be considered as resulting from a lack of scientific background and/or insufficient knowledge.

6.3.1.3. Making use of everyday knowledge

When facing iconic representations that do not fit to their interpretative capabilities, students' interpretations are grounded on previous knowledge, which may be, in some cases, alternative to scientific knowledge. As a consequence, the image does not help students to learn new concept or information.

6.3.1.4. Giving detailed explanations only referring to graphical signs

Often, students' interpretations do not take into account the conceptual meaning of an image's graphical elements.

6.3.2. About the list of features of images associated to detected students' difficulties.

The 'list' of features of the images, designed by the research teams, has shown its usefulness to categorise the students' difficulties. The subheadings are results based.

6.3.2.1. Images requiring interpretation of the roles of elements representing both real world and schematic or symbolic entities. (R/S)

Students give a prominent value to real world elements, transferring their everyday role/function to the interpretation of the image. As a consequence, iconic elements intended to be a metaphor end up with connotations added to them, especially in the case of younger students. On the other hand, for older students, these iconic elements seem to facilitate the interpretation of the associated abstract images.

6.3.2.2. Images constituting on-screen graphs, representing data being collected in real-time experiments, where external observable processes and graphic representations need to be related to one another. (RT)

The analysis of the students' answers to this kind of documents allows identifying some specific features of real-time graphs that may lead to difficult interpretations.

Ideal versus Real (*RT-IvsR*)
Students are commonly used to deal with mathematically regular graphs of functions and/or 'ideal' physics cases, and as a result, they may regard real-time graphs as being of poorer quality.
Global versus Local (*RT-GvsL*)
Tendency to insufficient differentiation between global and local points of view; e.g., focus on local features of a Real-Time graphs may make it difficult to detect the global trend.

The following results may be present also when students interpret textbook-like function graphs.

Gestalt (RT- Gest)
The students' attention is often mainly captured by the graph's shape, which becomes so predominant as to obscure the other information contained in the image and in the caption. The influence of the shape may trigger misinterpretations where the "seen" shape is linked to contents inappropriate to the represented situation.

Axis variables (RT- Var)
A misreading of axis variables leads often to wrong interpretation of a graph.

6.3.2.3. Images whose interpretation requires giving importance to or highlighting certain elements, often in relation to textual/graphical features which make or do not make them salient. (SEL)

The use of textual/graphical features often makes salient those elements which are not meant to be highlighted, according to the message represented. This leads to misreadings of the image. On the other hand, the interpretation of features used to highlight certain elements may give rise to problems, or may reinforce a wrong interpretation of the image.

6.3.2.4. Images containing elements which require appropriate readings of symbols, and which contain examples of synonymy, homonymy and/or polysemy of symbols. (SIM)

The use of elements that have more than one meaning is a source of difficulties for some students while others have shown the capacity to interpret similar signs as symbols of different concepts. On the other hand, the presence in a document of elements with very similar graphical characteristics may.lead students to infer a parallelism between them that may not be intended: for instance such elements may be interpreted as synonymous, or in relation to each other, even though they represent very different concepts.

6.3.2.5. Documents containing verbal elements, included in the image or used as captions, that need to be read as an important part of the whole. (VE)

Verbal elements included in an image can play different roles.
Verbal elements as captions: The students' interpretation of an image may change according to whether or not they have read the caption., Students do not tend to read the caption unless required.
Verbal elements inside the images: Students commonly have difficulties to establish relations between verbal and graphical elements; the efficacy of the verbal elements depends on whether or not the students integrate them in the document. The presence of words that students do not know or cannot relate to the context may confuse them.

6.3.2.6. Documents containing more than one image, thereby requiring interpretation of the relationships between the different images. (INT)

Integration of different images in the same document is favoured by 'connecting' elements allowing to establish links, for instance: similar elements, verbal elements used as tags and/or a careful layout of the images inside the documents. Students unfamiliar with graphical elements have more difficulties in integrating images.
The capacity to integrate images with different characteristics can be related to their modality. The following substructure may be suggested:
· Documents containing images with different modalities *(INT-dif):* A correct display of figurative and abstract images can facilitate interpretation of abstract ones; their integration in the document contributes to its global interpretation.
· Documents containing images with the same modality *(INT-equal)* Students use images of the same modality to create a common context of interpretation of both the different images and the document.

6.3.2.7. Images whose compositional structures are significant and thereby require the reading of spatial distributions and different representational structures. (CS)

Students tend to experience difficulties in interpreting images whose compositional structure is complex or has not been designed carefully enough. Some students, though, demonstrate a good capacity to interpret quite complex compositional structures.

6.4. Teachers' awareness and interpretation of students difficulties with images (WP 2.2)

An essential point when studying the use of images in the classroom is the teachers' awareness and interpretation of the students' difficulties reading images. It is necessary to know which are the aspects of images teachers consider problematic, and how they interpret the difficulties expressed by their students. Both will be determining factors influencing how teachers will use the images as didactical tools.
In the second subworkpackage, teachers were asked to respond to (comment on) the selected graphics or images, with regard to possible misunderstandings they may create or reinforce in students (or misunderstandings they may avoid). They were asked how they would expect students to read the graphics or images, whether they would expect problems, and what they might be able to do about such problems.

Crossing national reports about teachers awareness on students difficulties when reading images (Summary of WP2.2 results)

6.4.1. Teachers' comments on students' difficulties.

6.4.1.1. Low awareness of students' difficulties in reading images

This factor is reflected in inadequate foreseeing of the difficulties students may encounter. However, teachers' awareness of these difficulties increases when they are called upon to interpret and justify prototypical examples.

6.4.1.2. Focus on disciplinary aspects

Teachers tend to justify students' difficulties in terms of disciplinary aspects. They often consider images either as readily understandable or, at the opposite end of the scale, as too difficult to be interpreted by students.

6.4.1.3. Differences in the diagnosed obstacles

The features of the images detected by the teachers as being sources of difficulties do not match completely with the features detected as sources of the students' difficulties in the analysis of the researchers. Those most commonly mentioned by the teachers are SEL, VE, RT-Gest, and R/S., while INT and SIM figure less frequently.

6.4.1.4. Difficulties common to both students and teachers

The list of features (See Table 3) used for the analysis of the by the latter, has also proved to be useful to analyse teachers' answers related to graphical elements. The teachers' answers also suggest the presence of difficulties reading images similar to the ones found in the analysis of the students' answers.

6.4.2. Teachers' suggestions for changing the images to overcome students' difficulties (WP2.2)

6.4.2.1. Addition of verbal elements

Some teachers suggest the addition of more verbal elements in the document. This suggestion is coherent with their diagnosis of students' difficulties in terms of disciplinary concepts

6.4.2.2. Requirement of actions on relation to the images

According to the view that images do not convey ideas by themselves, teachers suggest verbal explanations of the images when used in class and of the concepts being represented.
In the case of RT-graphs, some teachers suggested carrying out more experiments.

6.5 Teachers transformations' due to the use of images in class (WP2.3)

This part of the WP2 deals with the teachers' use of images in class: how they adapt and transform them in the teaching/learning process. We aim to study the characteristics of the changes operated by teachers on proposed images to be able to conjecture the mechanisms of the underlined transformations.
The data and analysis from WP2.1 and WP2.2 could be used to inform an investigation of the way teachers use and deal with images and graphics in the classroom, in the context of innovative teaching sequences. The teaching strategies chosen for investigation will be ones in which visual communication plays a significant role essential to the subject matter and to the nature of the innovation, in which the teaching strategy used needs to take account of students' potential difficulties in reading images (for example, visual representations of optical phenomena; abstract visual representations of energy transfers; graphics generated in real-time interaction with computer simulations or data-acquisition and display systems).

Crossing national reports about Teachers transformations' due to the use of images in class (Summary of WP 2.3 results)

Reports from three research teams (those from Italy, France, and Spain, see RW2) are the source data from which cross-site analysis about the above-mentioned issues is carried out. All transformations detected by these research teams have taken place through the analysis of the teachers' use of images:

a) working with different images (common textbook images (FR), new textbook images (SP) or Real -Time graphs (IT)).
b) during class sessions (SP and IT), or during an interview after a training session (FR).

The different conditions regarding in-site-data have an effect on all transformations encountered, with special emphasis on the kind of images being used by teachers. However diverse the nature of this transformation may be, some common patterns can be perceived. The following is a summary of teacher transformations when using images:

6.5.1. Transformations related to the use of the visual language

6.5.1.1. Changes in graphic elements

Changes in the visual elements, i.e., eliding, adding and changing the graphical characteristics of the visual elements: shape, size, spatial arrangement, ... These changes affect the meaning of the image by affecting both the meaning conveyed by the visual element (the quantity, the action being represented, etc.) and the meaning represented by the relationship between the visual elements of the image (classification, connected concepts, etc.)

6.5.1.2. Changes related to verbal and mathematical elements

The meaning conveyed by verbal and mathematical elements is related both to their spatial arrangement with respect to the visual elements and to their linguistic or mathematical meaning. Adding those elements to an image results in reinforcing part of the meaning of that image, or even in changing global meaning. Changing or adding new verbal elements might alter the meaning both of graphical and related verbal elements.

6.5.1.3. Changes of the criticism and awareness of students' difficulties with training

After a teacher training course, focused on conceptual issues, teachers show an increasing awareness of students' reading difficulties; they propose changes to the images used in order to avoid such difficulties. Teachers also show an increasing tendency to make global consideration of the images, instead of restricting their consideration to only a few aspects. These changes also seem to affect teachers' view on the role of images in class practice.

6.5.2. Transformations related to the educational role assigned to images

6.5.2.1. Weak addressing of graphical features

Teachers do not usually teach the elements of the visual language involved in the image, not addressing aspects such as similarity of symbols or integration ideal versus real in their class. Some teachers, for instance, let the students decide the design of the documents and do not correct them afterwards. Other teachers do not seem to pay enough attention to the students' questions on this matter. This transformation reduces the effectiveness of images in teaching science.

6.5.2.2. Insufficient awareness of the educational advantages of using good quality images

Transformation of RT-graph optimisation might affect the role of such documents in lab work. The addressing of related scientific concepts is diminished by not properly modifying the settings of the software. Looking for quasi ideal graphs by modifying the experimental conditions of the experience, instead of addressing the specificity of RT-graphs can be consider a transformation of the educational role of these documents.

7. Work Package 3: Transformations when 'adopting' innovative sequences

This chapter had been written on the basis of the transversal report*: Investigation on teacher transformations when implementing teaching strategies*. RW3, Viennot, L. and Balzano, E., Chauvet, F., Giberti, G., Gomez, R., Hirn, C., Monroy, G., Ogborn, J., Pintó, R., Sassi, E., Stylianidou, F., 1999.
(http://blues.uab.es/~idmc42/document/index.html)

7.1. Studying the transformative process on defined innovative sequences

The study research *"Transformations when 'adopting' innovative sequences* (Workpackage 3) addresses the question of the nature of difficulties arising when teachers are expected to adopt an innovative teaching sequence. Our goal was to analyse in detail how teachers' non-neutral interpretation of a proposed teaching sequence may result in transformations with important conceptual consequences.
As recalled in the Italian National Report on this WorkPackage (Monroy et al. 1999), « the introduction and maintenance of didactic innovation in the school system is a complex process involving many components playing different roles and the relevance of the research about teachers transformations is supported by several undeniable evidences. Among these a non-exhaustive list is:

1. innovation at school, and particularly in science education, is increasingly needed to foster a better scientific literacy of the citizen;
2. the teachers, main actors of any innovative didactic process, necessarily do not passively implement the intentions of innovation's designers and need positive assistance in coping with the transfer of didactic innovation into the actual class-work;
3. policy makers and people in charge of teachers' training programs need recommendations coming from research results about how the innovation is transformed according to the boundary conditions existing in the schools and the global world of the teacher.

The predominant idea orientating the research, as stated above, is that of *transformation* of didactical intentions by teachers. This means that we have not tried to analyse "difficulties" as such, but that we refer our observations to precise didactical intentions.

This perspective should not be taken for trivial nor confounded with the concern of consulting teachers during the process of designing and implementing a new teaching sequence, which is not a new idea. Any reasonable committee in charge of developing a new curriculum includes some experienced teachers in its work, to a certain extent, whether great or small. But, this does not mean that, in implementing innovations, teachers' main transforming trends are consciously taken into account. This, in our view, requires research beforehand. Amongst the designers of innovations, while there is a rather diffuse consensus in valuing and taking into account the students learning difficulties, this is not yet the case as far as the transformations done by the teachers are concerned. One may object that a lot of investigation has been done on teachers, especially concerning their views on the nature of science (see for instance Brickhouse 1990, Desautels et al. 1993, Koulaidis & Ogborn. 1995, Millar 1988), their views and expectations about labwork (see the European Project: Labwork in Science Education, Séré et al. 1998) as well as their understanding of different subject matters (for instance: Viennot and Kaminski 1991). Such information is very important to understand how teachers act in classroom. But it does not encompass all the aspects of teacher actual practice, especially the fine grained strategies that so critically determine the outcomes of teaching.
The research results on the transformations done by teachers when adopting innovative teaching strategies are important elements to make the design and communication of research-based teaching strategies easier.

If the transformation of a message on its way to its target is to be investigated, this message has to be as clear as possible at the outset, at least for an identified group. As researchers in didactics, we chose innovations that are inspired by a didactic reflection and, to a greater or lesser extent, research based. We selected and underlined the aspects that we consider critical in each innovation, in order to focus on their possible transformation by teachers. For a given innovative sequence, we locate connections between precise didactic intentions and specific types of action by the teacher

So, on well planned, documented innovations, with specific didactical intentions, have been described in written texts. Actual teaching strategies employed to relate to teachers' conceptual difficulties, to their epistemological views, and to their previous practice have been analysed. .
This has been done with six innovative sequences which were specified in detail by the innovators themselves, all the more so when a research team in didactics was involved in its design.

The corresponding list is, (by alphabetic order or countries):

«Optics at grade 8» in France	(national scale);
«Colour» in France	(local scale);
«Motion and Force» in Italy	(local scale);
«Energy Transfer and Degradation» in Spain	(local scale);
«Energy and Transfer» in United Kingdom	(national scale);
«Energy and Change» in United Kingdom	(local scale).

It is worth stressing that, beyond the differences of topic and context, the selection that we operated is inspired by common views on the teaching learning process, especially the decisive importance of the learner's conceptual construction and the valuation of coherence. This goes with the fact that the innovations under scrutiny at least witness an effort in such directions.

Having thus clearly specified what teachers were expected to aim at in their teaching strategy, i.e. what was the "frame of reference" of all our observations, we focused on these aspects, thus leaving aside many other possible ways of looking at the same materials (a situation which arises quite generally in research, of course).

Research questions

In this WP, the specific questions that are addressed are:

1. *-What specific requirements are expected of teachers in some selected well-defined curriculum innovations in science?*
2. *-How do teachers understand these expectations? How do they act on these understandings in the classroom? What transforming mechanisms can one conjecture to be involved?*

We rely on *multiple data sources* in order to triangulate our observations. The materials used are of the following types, so far as is practicable in different cases:
1a- *Interviews* with teachers concerning the texts of official instructions, or more generally from written texts defining an innovation, this in order to see what teachers read into the text, and what they think they will keep/ modify in their practice.
1b- *Interviews after training* sessions concerning an innovation to see what teachers consider salient in the received training and what they think they would keep/ modify in their practice.
2- *Logbooks* written by teachers, or interviews after teaching, with their analysis of "successful" and "not successful" episodes to see the planned conceptual path: respective emphasis, order of introduction, chaining; how they organise experimental activities
3- *Tasks* teachers give students to do to see what they chose to assess their conceptions of desirable outcomes.
4- *Class observations*: video recording or observational, or fewer case studies over a longer period to see what purposes appear to orientate activities,
how teachers conduct debates in class concerning the conceptual target of the sequence.
5- *Textbooks* published after a change at national scale (France and UK) to see what the textbook writers have chosen to emphasise, and how, with attention to the part played by images.

Data of the different types are connected to actual practice to different extents, respectively:

type 1	what teachers say they will do; (WP3.1)
type 2,	what teachers say they have done; (WP3.3)
type 3,4	what teachers do in the classroom. (WP3.3)

Data of type 5 (textbooks; WP3.2) have a multiple status, possibly reflecting:
-the practice of the writer, who often is or has been a teacher
-what the writer imagines that teachers expect

-actual inspiring sources for the teachers who use them.

Thematic analysis prevails, strongly orientated by the specific conceptual goals of each sequence.

The below table sums up the samples corresponding to each data source and topic/country for the investigations in the four countries which participates in this work package, textbooks excluded. In all, this research study involved 171 teachers from four countries.
As explained above, textbooks are also likely to be related to teacher practice through several channels. French and UK teams have examined, respectively, five (topic: Optics) and twenty-four (topic: Energy and Transfer) textbooks.

Country (data collection) ***Topic/country***	**Inter.bef.T. /** ***quest*** before teaching**,** on texts	**Logbooks/** ***Interviews*** after teaching	**Tasks**	**Class observation**
France ***optics gr.8 (Fr)*** ***colour =gr.11 (Fr)*** ***motion/force (It)*** ***energy (Sp)***	 **N=11** **N=10** after training* ***N=23*** ***N=34*** *after training* **N=3** **N=5**	 **N=11** **N=6** ***N=2*** *after training*	 **N=8+8** teachers (39 tasks) N=3**	 **N=2** (6 lessons, video)
Italy ***optics gr.8 (Fr)*** ***motion/force (It)*** ***energy (Sp)***	 **N=4** **N=6** includ.4 after training **N=3**	**N=4**	**N= 2** (77 students worksheets)	**N=7** (notes)
Spain ***optics gr.8 (Fr)*** ***motion/force (It)*** ***energy (Sp)***	 **N=4** **N=3** **N=13**	N=6		N=7*** (video) N=9*** (notes)
UK ***energy/transfer (UK)*** ***energy/ change (UK)***	 **N=5** after training N=3	 ***N=4*** ***N=2*** *(7 interviews) one after training*		 N=4 (6 lessons, notes) N=2 (7 lessons, notes)

*Unless specified, teachers have had no training concerning the innovation under scrutiny.
**Not in bold: teachers already counted in a preceding column.
WP3 Data collection: in total, this research study involved 171 teachers from four countries

Our data sources were variegated, each one concerning a relatively small sample of teachers, and being analysed, broadly speaking, in a qualitative register. In all, 171 teachers, from four countries, have been consulted, this « consultation » reaching sometimes about twenty hours of discussion and observation for a given person. The teams in charge of writing the textbooks that have been analysed constitute a noticeable, although indirect, extension of this sample.

We attempted to collect information concerning what the teachers selected and transformed in their understanding of the instructions describing a given innovation. We also considered how the textbook writers had interpreted the proposed « music ». Textbooks indeed may witness teachers' transforming tendencies in at least in two ways. First, textbook writers often are, or have been, teachers themselves. Second, they adapt, in principle, the product to the market.

7.2. Cross comparison between different data sources for a given innovation

In such a research structure, the question which arises is that of the cross comparison of the tentative conclusions suggested

1. by each data sources for a given innovation,
2. by investigations concerning diffrent topics and contexts

Having analysed each sequence in the terms proper to it, we have looked for transversal aspects in our results, in order to point to some particular risks of transformation, whatever the topic, in the process of 'transmission' of innovations to (that is, through) teachers.
Cross comparison between these data sources constitutes a critical basis for our conclusions
For three of these innovations, the first part of the investigation - on what the teachers selected and transformed in their understanding of the texts - has been replicated in two other countries (see above Table). Three countries have been involved in obtaining such complementing data: France, Italy and Spain; each country responsible for a given innovative strategy passed on the corresponding texts to the (one or) two others, which have used them to conduct a parallel investigation.
This first comparison, between results from three different national contexts for a given topic, suggests a convergence, beyond the emergence of some local trends, this as far as a comparison between samples of a few units is meaningful.

7.3. Crossing national results from different teaching sequences (WP3)

The Annex: *Investigation on teacher transformations when implementing teaching strategies. RW3,* 1999. Viennot, L. and Balzano, E., Chauvet, F., Giberti, G., Gomez, R., Hirn, C., Monroy, G., Ogborn, J., Pinto, R., Sassi, E., Stylianidou, F. (http://www.blues.uab.es/~idmc42) *contains all the results*

The process of cross comparison has also involved different innovations After comparing findings about different innovations, we attempted at localising rather general and possibly transversal transforming trends.
The next paragraphs illustrate some strong points on which convergence is patent.

7.3.1. "Motivating" is not enough

A preliminary remark is that it was very frequent to observe in teachers an open global attitude toward an innovation. 'It is very motivating', it was said. Very often, the active role devoted to learners was emphasized, especially when computers were in play as with MBL. Optics, Colour, and the part played by everyday life situations in the addressed contents were positively commented upon, especially by Italian teachers. Sometimes the motivation seems first that of the teacher, supposedly transferable to the learner. Thus concerning 'Energy and Change', a teacher seems to be very much in resonance with the innovation proposed, which, he finds, is unifying from a conceptual viewpoint. The end of this story, however, reveals that this teacher 'has not espoused other equally fundamental characteristics' of this innovation.
This is a very frequent case, in all our investigations, that some important transformations effectuated by the teachers are not related to a conscious rejection of the innovation as such.

Even if judged 'motivating' by a teacher, be it for the pupils or for the teacher her/himself, an innovation may be transformed to a large extent by this teacher. This may appear at a declarative level, when the debate is about precise teaching actions, or, still more clearly, when such actions are observed in the classroom.

Although we do not consider that the 'what (to teach)' and the 'how (to teach)' are to be considered separately in characterising an innovation and its transformation, we present these two faces of a complex reality with different dosages in the following items.

7.3.2. Reconsidering the conceptual paths: rigidity

Important transformations are observed in all our investigations concerning the respective emphasis on the taught concepts, their mutual relationships, their linkage.

An extreme case is when a whole area of the proposed innovation is neglected, as Friction in the 'Motion and Force' case. Friction is exactly what traditional teaching of mechanics has always evacuated, the perturbing element which is seen as hindering a proper illustration of Newton's laws. It's rejection by Italian teachers probably needs no long discussion. The phenomenon, however, is spectacular enough to be acknowledged.

A more partial neglect of a non classical topic can be observed, as in the case of vision and perception (is it also because vision is at the same time a conceptual target and a privileged means of observation, its link with perception throwing suspicion on the conclusions that can be drawn from observation?).

Much more often, we have observed a maintained interest, in teachers, for a topic which is 'crossed' by the innovation without being a target in itself. Such a partial occultation, in the designers' wishes, may be due to simple selection, or this topic can be considered as to be avoided for various reasons: it may be misleading because compatible with naïve ideas if not thoroughly explained (as the 'materialised ray'), or it can lead to conceptual incoherence according to the designers, as energy 'transformation'.

This maintained emphasis on an undesired content is seen, in all the considered innovations, to be juxtaposed with the take-up of new conceptual elements.

This can intervene at a verbal level, an old vocabulary being mixed with a new one, as in UK when 'energy is (said to be) transferred from one form to another', a major feature in the teachers' transforming action for the corresponding innovation.

This may go with the use of new images, themselves attached to a very specific understanding of 'Energy and Change', after a preliminary classical use of images representing energy flows, which goes with a real difficulty to reconcile these two views.

The same kind of transformation and difficulties appears in Spanish teachers confronted with a new conceptualisation of 'Energy Degradation', which is incompatible with maintained allusions to a loss of energy.

Clearly, several things, which are not exclusive, may have happened when such juxtapositions are observed.

It can be a simple rigidity, a refusal to renounce to a 'fundamental' aspect of knowledge, a view of teaching as if there was a unique path from one notion to another, with compulsory steps and the need for an extensive teaching at each step. This seems to be the case for the quasi-unavoidable spectra in teaching colour. The only kinds of damages here, but these can be of consequence, are inflation and loss of sight of a conducting thread.

It may also happen that a conflation of old and new strategies witness a negotiation, supposedly to make the "new" acceptable by the pupils. Often, indeed, it is said that an innovation is interesting but "difficult" for pupils - or is it so for the teacher himself? A large proportion of Italian, Spanish and UK teachers are in this case, concerning the four respective innovations. Hence the fact, for instance, that some teachers recommended to use "energy transfer" preferably for younger pupils, or for teaching transfers due to temperature differences, or else to use "energy transformation" for teaching energy efficiency, so that no teacher confined him/herself to a strict use of "energy transfer".

It may also happen that the new conceptualisation is not understood by the consulted teacher, who is not at ease with the content, a fact revealed by the revisited presentation which is proposed. The topic of Energy is especially propitious to such a destabilisation. Of course this may be in resonance with the preceding features of teachers' reaction to innovation.

Some non traditional topics are neglected, totally (friction) or partly (geometrical condition for vision). More often, there is a trend to conflate the « new » with the « old ». This may result in hypertrophy, and/or incoherence. This may stems from a view of teaching as necessarily following a unique (traditional) pattern, a wish to negotiate with the difficulties, an incomprehension of the (revisited) content.

7.3.3. Links are not put in evidence

This is a major feature of teacher transforming action in all the investigations reported here.

The Spanish teams noted that promoting the ability to use explanations or interrelations of real phenomena from different theoretical models or from different level of analysis was a goal undervalued by the consulted teachers. The same thing was observed, concerning the Spanish innovation, about the ability to manage common register, scientific register, verbal language and mathematical language.

The example of Optics in grade 8 is also instructive. The articulation and chaining between concepts observed in teachers' strategies seem particularly far from what the designers suggested. For instance, the questions on delimiting dark and bright areas on a screen and questions about what is visible from behind such and such a hole in that screen are simply juxtaposed, and not linked, whereas this was presented by the designers as an opportunity for conceptual construction, as well as for differentiation, of two concepts: rectilinear propagation and geometrical necessary condition for vision.

Other links disappear as if one of the involved concepts should be extensively taught for itself instead of serving as a tool for the teaching of another concept. This is the case for colour in « Optics in grade 8 », which a number of teachers separate from diffuse reflection, whereas it was intended to serve this conceptual goal.

Still concerning colour but regarding the sequence solely devoted to this topic, the suggested link between the blockage of a coloured light, in the set-up of « coloured shadows », and a process of absorption of light by a filter is not exploited.

The Italian team also notes that, in the teachers consulted about « Motion and Force », the different activities are perceived as « flashes » and are addressed one by one and in isolation. As they say « a difficulty that all teachers seem to have is how to organise and integrate the different activities: for instance: - mixing traditional and real time experiments, - explicitly addressing the connections and conceptual sequencing between the different activities performed, - connecting data collection and data analysis etc. »

It is noteworthy that the whole story of links often resides in the consideration of apparently « small » details. This is quite clear for instance in the case of the investigation about Colour sequence in France. The consulted teachers «neglected to bring to bear some crucial details, such as questioning about light instead of about tints. Doing this, they missed the point of linking the different phases of their teaching in the frame of the suggested global rationale, which is focused on the story of light from the source to the observers' eye ».

It may also happen that a dramatic change is observed in teacher practice, with respect to the designers' intention, due to neglecting the suggested chaining. Thus, in the « Motion and Force » innovation, a global transformation is detected, resulting in an overturn of the rationale: the ideal case/model instead of being the end point of a complex path is taken as the starting point.

Links- between different approaches or languages, between concepts and activities, conceptual paths - are not put in evidence. There is a quasi-general lack of consideration of links. The recommended order (for instance « from real to ideal »), can be completely inverted in teacher practice. Often, concepts are taught, and activities are organised, in isolation; the fine-grained specification of a chaining between concepts is not taken-up, at the expense of the global rationale, and of conceptual coherence.

7.3.4. Learners' previous ideas, language and learning difficulties are not really addressed

The consulted teachers often seem to be aware of the learners' previous ideas, language problems and learning difficulties, and may willingly claim that these deserve attention. For instance, the Italian and Spanish teachers mentioned this point about the « Force and Motion » Proposal. Or else, the French teachers, concerning « Optics at grade 8 », seemed to be conscious of the difficulties linked to vision. This might well be a first step of the positive outcomes of research in didactics conducted since twenty five years.

However, as stated by Monroy et al. (1999) in their National Report, for many teachers, « mentioning is addressing », seemingly. Common language terms were often simply corrected as « mistakes ». The common-sense knowledge was seldom addressed as such. As these authors explained, «during the observed sessions none of the teachers placed attention in eliciting the students' naive ideas: in the Force part these ideas came up clearly in the students worksheets, but their discussion and eliciting was postponed to a later session. Another teacher, using a sharp « ask-answer » approach, never really gave the students the possibility to recognise their common sense knowledge and therefore to build a disciplinary knowledge ». Another clue of this weak addressing of common sense knowledge and learners' difficulties is that it appears, regarding the different areas of « Motion and Force », as content-dependent.

Along the same lines, the careless attitudes that were observed regarding images in Optics or about Colour clearly witness a lack of consideration for learners' previous ideas: drawing a « ray » in yellow and a « shadow cone » in grey is too compatible with the idea that light is an ordinary object visible from the side not to call for explicit explanation. The same can be said regarding triades of coloured

circles indifferently used to illustrate additive and subtractive colour mixing (see National Report Chauvet et al. 1999).
In the same way, the « materialised ray » in Optics, is a perfect example of « tempting the devil » (if the commonsense knowledge was « the devil », which it is not) .

In short: *Learners' previous ideas, language and learning difficulties are acknowledged but not actually and consistently addressed.*
Problems with teaching materials (texts, images, activities) likely to reinforce these previous conceptions and learning difficulties are not attended to.

7.3.5. Planning learners' activity, especially during practicals

The low consideration of learners' difficulties by the consulted teachers is but an aspect of a more general trend. It is patent, for instance in the interviews and logbooks about Optics (Chapter I), that when describing a practical activity, teachers only explain what will be shown and with which materials. Chauvet also reports about Colour (Chapter II), that the consulted teachers did not specify in detail how they would organise their students' activity during practicals, and she shows, with the example quoted above -questioning on the amount of light diffused versus on its tint - how such a detailed planning matters.
Similarly, the Italian team comments that, although the conceptual framing of the experiments is a difficult task and a very important transversal skill that might be acquired by the students while performing lab activities, it often happened that only the teacher (or one skilled student) was performing the experiment, while the other students stood passively in their seats. This is in striking contrast with the fact that the teachers said, in interview, to appreciate the lab work as « motivating » for the students (see our first point in this section). What may appear as contradictory in such facts is not so if the detailed planning of a practical activity is not a relevant concern for teachers, and if, as commented below, « to see is enough to understand ».

The cognitive structure of the students activity is not planned in the same detail as the practical aspects. Quasi unanimously, only global descriptions of activity are stated by teachers, no fine grained specifications of chainings, links, types of questionning, orientations of debate are specified.

7.3.6. The Prediction- Experiment- Comparison strategy is under exploited

Borrowing the Italian formulation (PEC) of a style of working which we consider critical in constructive learning, we can examine what the teachers have done in this respect, this in the three investigations which are especially relevant, because involving many experimental activities: « Force and Motion » , « Colour » and « Optics at grade 8 ».
Starting with the last one, a very striking result emerged from all the data souces, as explained above. Athough repeatedly mentioned in the correponding Official Instructions, the idea of prediction was simply absent from the teachers' comments and observed actions. This meets a finding of the Labwork in Science Education European project (Tiberghien et al. in Séré et al. 1998), where prediction is not one of the component of labwork activity, according to the analysed worksheets.

The idea of reasoned prediction before experiment is either totally absent or envisaged in a limited register: prediction is not directly followed by any experiment, or else is practiced in the register of motivating discovery.
An interesting exception is observed concerning Colour, after training.

7.3.7. «Seeing is understanding», (therefore?) «see what I want you to see»

Such a slogan seems to have been widely adopted. The first part - « Seeing is understanding » - strikingly emerges from the investigation about « Optics ». This fact is corroborated by interviews (before teaching, privileging the demonstrations at the expense of explanations), logbooks (which only specified what was shown and with which materials), class observations (where it was also patent that the pupils had to see only what the teacher wanted them to see). The emblematic « materialised ray » and its cortege of teacher satisfaction fully illustrates this trend.

The linkage we suggest, between the - « Seeing is understanding » - well known epistemological slogan and the no less well known « see what I want you to see » syndrome, is not a very risky assumption. Not surprisingly, it has not been expressed as such by any teacher.
Although this might seem paradoxical, this linkage might explain an attitude which rejects obvervation, at least that of real phenomena.
As recalled above. the Italian team notes, about « Motion and Force », that, contrary to the instructions, the ideal case/model is taken as a starting point. The « dirty » aspects of real motions and of artefacts due to the set-up might well be, more or less consciously, considered as obstacles on the way of this direct connexion between observation and comprehension. An extreme case of such an attitude might be to renounce to experimenting because it is definitely too difficult to « clean » experiments properly. This might concur with the trend to simply reproduced–traditional teaching to explain why, as noted by the Italian team, textbook study and chalk-and-word lesson are often privileged.

Briefly:
Observation is valued at the expense of explanation. «Seeing is understanding» seems to be a widely spread slogan. It might go with the « see what I want you to see » syndrome, and be related to the following point, among other possible causes.
A wish to start from « cleaned » facts is observed. This feature is especially striking regarding « Motion and Force »: the suggested conceptual path « from real to ideal » is reversed, the starting point chosen by teachers excluding, in particular, friction.

7.3.8 .The importance of devices

It has been strongly underlined in the investigation about Optics (Hirn 1998, Hirn and Viennot 1999) that a one-to-one linkage seems to orientate teachers' strategies: the use of a given device would entail a given didactic approach. Some new devices, being approved and at least partly understood, appeared as efficient vehicles of new intentions, as were the punched screens for instance, whereas undesired traditional devices -optical benches, slits and opaque screens or materialised tracks of light - seemed to drag along with them their classical - and non recommended - pedagogical use. This is also the case concerning Colour , teachers often conflating the old with the new, especially through the - non recommended - use of a classical set-up such as Newton's disk or devices for spectral analysis.

On the one hand, this kind of tyranny of the devices may be regretted as a very limiting factor.
Thus when a teacher cannot admit that a filter, traditionally used to illustrate and effectuate selective transmission, is also necessarily, if visible, an agent of diffuse reflection, the blockage of simple coherence is obvious.
Or when the MBL is seen as defining in itself a Proposal, and warranting success by a simpe effect of motivation, whereas it is underexploited as a cognitive tool, the limitation of the teachers' didactic analysis is patent.

One the other hand, it is not deniable that, via MBL, new perpectives on the teaching of mechanics have been efficiently fostered. If the mere description of the corresponding innovation in written texts reveals a poor vehicle for the corresponding didactic intentions (see the weak resonance in the French teachers), an experimental practice of the tool noticeably favours the take-up of the Link to perception , a major wish of the designers.
Couchouron et al. (1996) already underlined the possible interest of focussing the attention of teachers on a given device or object which was not traditionally considered before, this in order to foster the take-up of new didactic intentions. They gave the example of the connecting wire, which was introduced as a topic in itself in the French syllabus for grade 8 in 1993 (BOEN 1992) and seemed to have captured the teachers' attention regarding the distinction between Tension and Intensity. This first hint is strongly supported by our investigation.

In short: *A one to one linkage between a given device and a given didactic approach is observed The maintained use of a classical device drag along with it traditional strategies. The adoption of a new device can foster the - at least partial - take-up of new strategies. Designers might usefully take such linkages into account, to avoid rigidity and to favour the implementation of new strategies by backing them up with new devices*.

PHASE 3

Crossing results on parallel research studies about the implementation of innovations across five European countries

8. Workpackage 4. Teachers Implementing Innovations: Transformation Trends

This chapter had been written on the basis of the transversal report *Teachers Implementing Inovations: Transformations Trends, RW4*, Pintó, R., Gutierrez, R. and Ametller, J. Andresen, O, Balzano, E. Boohan, R., Chauvet, F., Colin, P., Couso, D., Giberti, G., Hirn, C., Kolsto, S.D., Monroy, G., Ogborn, J., Quale, A., Rebmann, G., Sassi, E., Stylianidou, F., Testa, I., Viennot, L. , 2000.
(http://blues.uab.es/~idmc42/document/index.html)

Research question and method of analysis for the Phase 3 (WP4)

8.1. Research question

In the STTIS Project, results obtained from the inductive path, followed throughout the in-site analysis with data about an innovation in a country, were crossed and clustered in the National Reports. The cross-checking of different National Reports, corresponding to each type of innovation, led to Transversal Reports RW1, RW2, RW3.
These Transversal Reports (and, when necessary, the 15 National Reports), referring to the implementation of the three types of innovation, provide data for the cross-checking cross-site analysis, whose contrast and comparison will lead to the general clusters. This constitutes what has been called Work package 4 (WP4).
In WP4 we have followed a back and forth strategy to search conceptual coherence between data, interpretation and generalisations.

This methodology led to study whether there are commonly-shared features in the teachers performances when they are faced with innovations. Therefore, the following research question is to be tackled:

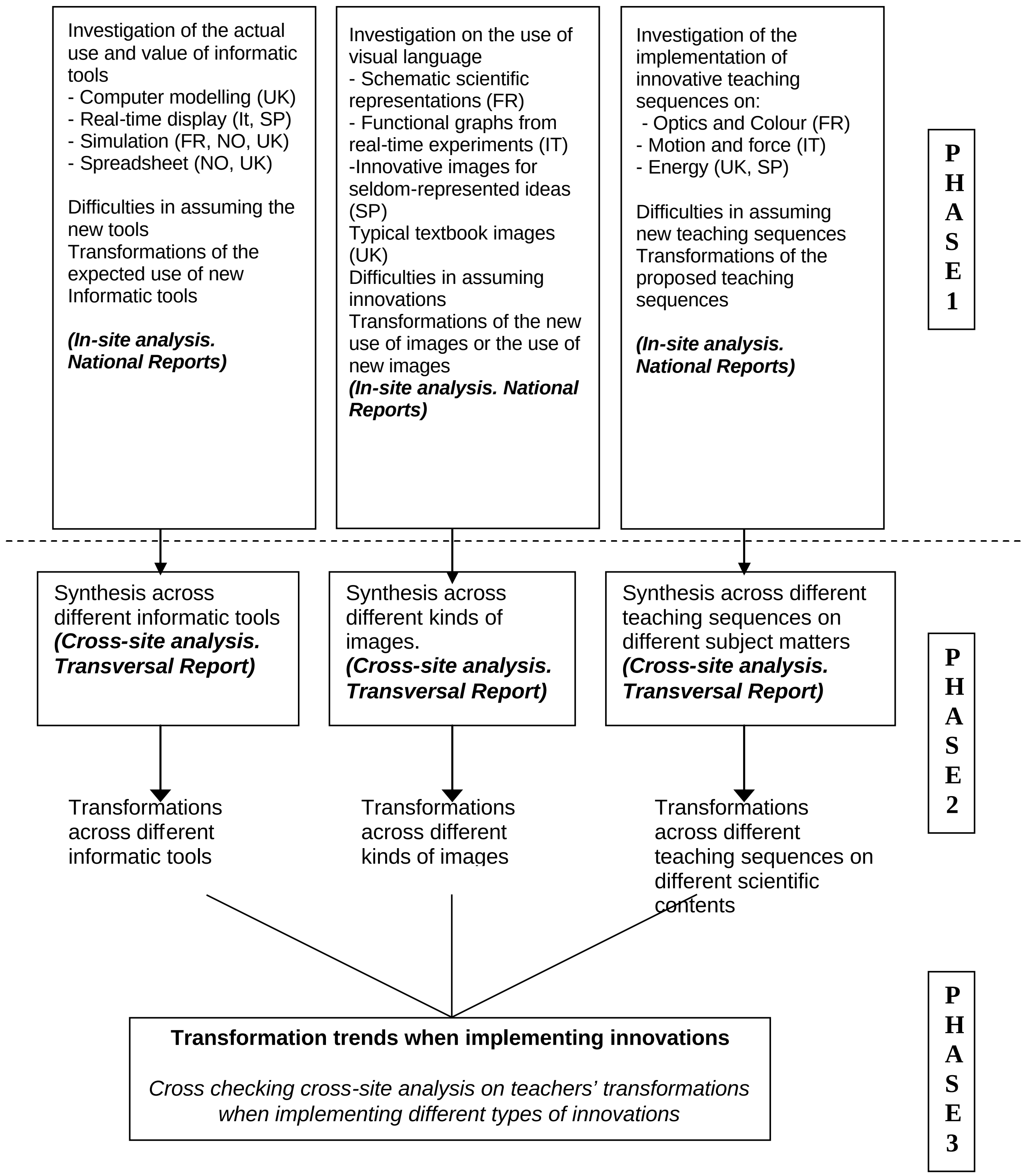
> *Can general trends be inferred in the transformation undergone by teachers when facing different curricular innovations?*

An answer to this question should provide us with an insight into teachers' performance following the proposal that their teaching be undertaken differently, or after being given new educational resources.

8.2. Data sources and methodology for WP4

As stated before, in the STTIS framework, the empirical data were gathered and analysed qualitatively, guaranteeing that data are validated at each site (in-site triangulation of different sources). Results obtained from the inductive path, followed throughout the in-site analysis, were crossed and clustered in the National Reports. The crosschecking of different National Reports, corresponding to each type of innovation, led to Transversal Reports RW1, RW2, RW3.
These Transversal Reports (and, when necessary, the 15 National Reports), referring to the implementation of the three types of innovation, provide data for the crosschecking cross-site analysis, whose contrast and comparison will lead to the general clusters. This constitutes what has been called Work package 4 (WP4). In WP4 we will follow a back and forth strategy , as it is considered by several authors (Miles and Huberman 1984, Yin 1989, Merrian 1988, Denzin and Lincoln 1998) as an effective means of searching conceptual coherence between data, interpretation and generalisations.
The schema below, shows a summary of the different steps taken in this research.

8.3. Summary of the research steps



This schema is focused only on those aspects of the STTIS research project related to Transformations of innovation

8.4. General trends in innovation transformations

From the analysis of the various documents, some general trends can be identified.
These trends may be considered as operating when innovations arise.
In the subsections below, we will account for the common features identified in teachers adaptations and transformations when innovations of a diverse nature were implemented during their courses: innovations related to the introduction of computer tools in science courses; innovations related to the use of images and graphical representation; innovations related to new strategies in teaching scientific content). The commonality of these features facilitates their consideration as relatively general trends.

They have been inferred from a cross-checking cross-site analysis of the teachers' performances when faced with innovations of very different character. We can wonder whether these reactions, as transforming mechanisms that have operated in our teachers, are no more than a particular case of the human reaction when facing a novelty that is not under their control. Future researches, including other human groups, could assess it.

8.4.1. Fragmenting holistic views or approaches

Teachers have frequently been observed as presenting topics, concepts and activities without providing an overall view. Instead of helping students to understand the scope of the topic, to realise what issues may be solved by a given concept, to understand how concepts are linked or the global goals of a specific task, teachers give a detailed presentation of each step. This trend has been observed in many situations, for example:

- When every topic from a given syllabus is taught separately, with no inter-connecting theme (RW3-FR).
- When, with programmes having innovative sequences that emphasise concept coherence, the relationships between related concepts are not given attention (NR3-SP, NR3-FR).
- When emphasis is placed on analysing concepts separately, disregarding the way in which concepts are related. in accordance with this strategy, each concept is taught per se (RW3, NR3-IT).
- When activities are introduced as "flashes", but without explaining the links between them, and therefore disregarding sequence chaining or interconnection (NR3-IT, NR3-FR).
- When deleting sections of an experimental script directed at communicating the goals to be reached. Instead, students have to follow the script worksheet without relating the various sections, etc. (NR1-SP).
- When concepts previously taught are only referred to in the case of absolutely necessity, thereby juxtaposing previous and current concepts. (NR3-SP).

- Introducing computer sets by considering their items separately (thereby preventing students from building a mental model that accounts for the whole set with all its items) can also be placed within this overall trend (NR1-SP).
- Integration of IT tools within the whole set of activities addressed to concept treatment is sometimes neglected. Computer tools are presented separately from the group of actions to be carried out, or from those strategies to be followed in acquiring knowledge (NR1-NO).
- When images are used, if at all, attention is paid to particular lines (whether symbolic or part of a graphical representation), but no global introduction is given.
- In some image transformation (i.e., drawing a ladder instead of a flow diagram for representing energy transfer) (NR2-SP) it can clearly be seen that teachers give priority to a particular aspect of the image. Consequently, the overall view of interrelated concepts within the proposed image is not tackled, leading to lose internal coherence.

Some teachers, after certain training sessions (on Colour), appear to modify this tendency. As criticisms were first made of specific aspects concerning the first part of the image, then their critic were global about the two images showed. Their criticisms of the two images shown were subsequently global (NR2-FR).

All these facts provide reason for concluding that teachers tend to focus on particular details rather than on given holistic views, whether teachers introduce concepts, propose activities or describe experimental sets, etc. It is as if the information were intended to be transmitted by being broken into pieces, without the connections being shown. We could say that the analytical function predominates over the synthetic function.

8.4.2. Modifying small but crucial features

The tendency indicated above of cutting global presentations into small segments, approaches, sequences, chains, etc. could perhaps be interpreted as a teaching resource for facilitating the assimilation of concepts, skills, etc. to be learned. In other words, it is possible to conceive of fragmentation as a means of approaching fine-grained detail, giving priority to the analytical over the synthetic process and to the acquisition of global views. However, when closely observing how certain small features are implemented, no attention seems to be paid to many crucial issues

Throughout the STTIS project, different kinds of curricular innovations are proposed for implementation in school or university classes. Many of these contain seemingly minor but in fact crucial[4] aspects for a better understanding of certain concepts, for more effective acquisition of certain given skills, or for a better representation of processes, etc. For example, a term used in only one way; an experiment presented in a different way; a new type of question to be used, new software, an image to be represented, etc. These 'minor' (though in reality, critical) modifications are often neglected by teachers, or re-transformed into something more habitual.

Examples have been found within different sections of the research undertaken, and from teachers belonging to the different countries:

- In the choice of software used for the treatment of satellite motion under Newtonian gravity, it has been observed that, instead of using spreadsheets, dedicated software was chosen, without apparently realising that this only illustrates satellite trajectory, without revealing the underlying dynamics. That is, the choice of the computer tool has led to a dynamically opaque presentation instead of a dynamically transparent introduction to satellite motion (NR1-NO)
- Additionally, when using certain software in Optics that implement rays but do not implement any permanent point source (bearing in mind that an understanding of geometrical optics in depth requires the consideration of systems such as ray transformers, as opposed to object-to-image transformers), a teacher tries to teach image versus object location and to draw a number of diagrams. The same could be said when, using this software, teachers do not use the dynamic aspect of the ray-diagram simulation, which automatically redraw the rays after changing or moving a lens or a mirror. They therefore loose the opportunity to show the students what is kept and what is moved when a location or a property is changed. (NR1-FR)
- A global strategy focusing on the story of light from primary source to the observer’s eye might be undermined if teachers fail to account for certain crucial details, such as questioning on light rather than tints in a Colour sequence, or when they dismiss pupils’ questions about the fact that a filter might not only transmit but also diffuse some degree of light. (NR3-FR)
- There are other elements that are not taken up in teachers' comments in a long and detailed plan of the sequence taught, such as the fine-grained specification of questions that promote discussion (i.e. the idea of questioning luminosity instead of colour, when faced with a ‘coloured object’ lit up by coloured light, or the steps to follow, and the links between, the different phenomena of colour) (NR3-FR).
- When teachers find that the difference between ‘energy transfer’ and ‘energy transformation’ concepts (NR3-UK) is insubstantial, representing merely a language/wording issue, it would seem that the global ontological change conveyed is not well perceived.
- When teachers dismiss or do not pay attention to any activity/exercise aimed at establishing a bridge between everyday language referring to “lost”, “consumed”, “wasted energy” and dispersed or degraded energy, they are loosing the opportunity to use science classes to help in understanding the real world from the scientific paradigm. Or, when heat transfer is assigned to

[4] An innovation could be interpreted as crucial or not, depending on the priority of the goals established by the designer. For example, making students use their own words to talk about phenomena that will be analysed in subsequent experimental work or attempting students’ mental representation of what will be analysed in forthcoming lab work may be considered crucial by some designers, yet may be seen as less so by others.

each temperature increase, regardless of the educational material being followed, they are presenting students with a contradictory definition of heat. (NR3-SP)

- The path of light through a lens is particularly critical for the status of lines drawn on images in optics: do they represent a real object visible from the side (‘materialised’ rays)? Are they used to determine zone limits (as determining which part of a screen is lit)? Do they illustrate a generic ray, as when illustrating diffuse reflection? Some teachers did not clarify such points. It seems that there is a certain carelessness with respect to images. (NR2-FR).
- An inaccurate way of drawing an energy flow diagram, transforming the large arrows into vectors, or “forgetting” the pictorial elements representing energy, loose the opportunity to convey the meaning of energy quantity, and therefore, loose the opportunity of referring to energy conservation. (NR2-SP).
- When real - time graphs are produced, careful addressing of system artefacts is crucial for distinguishing these from “irregularities” related to physically meaningful aspects of the studied phenomenon. (NR1-IT).
- In cases where prediction of an experimental result is made but is not related to an experiment, the educational value of the Prediction - Experiment - Comparison cycle is greatly reduced (NR3-IT).
- A crucial aspect of the use of real – time systems is the skill to use the most appropriate software options when addressing a given content. For example, the software allows comparison of the results of two experiments on the same graph. In some cases, such comparison was carried out by verbally recalling the trend of one of the graphs (NR1-IT).

Not taking note of small but crucial features is problematic, and at the same time, its importance is very difficult to communicate to teachers. When the issues appear to be largely unimportant, teachers may not notice them or may not be greatly preoccupied with changing them. This trend would once more confirm the view that it is only possible to perceive or observe those concerns about which we already have sufficient information.

8.4.3. Reducing cognitive demands placed on students

With respect to teachers’ interest in affecting students’ cognitive domains, different trends have been detected:

a) It has been observed that some teachers , though very few, turn every activity or problem into a cognitive challenge to be tackled by students (NR1-UK, NR1-NO, RW3, NR3-IT, NR3-FR, NR3-UK). This is achieved by increasing cognitive demands in the proposed activities, seeking abstract similarities, implementing a PEC cycle (Predictions /Experiment/Comparison), etc.

b) However, it has been observed, and in most of the cases studied, that teachers turn a proposed activity directed at cognitive development into a particular action to be carried out.

- Thus, for instance, students are asked to describe and classify objects rather than to provide coherent explanations [of a given theme/issue](NR2-FR).
- Instead of explanation-based examinations, ‘rote-learning’ type examinations are proposed (NR3-FR).
- Failure to pay attention to the graphical features of RT graphs can be interpreted as a transformation that leads to a decrease in the explanatory power of graphs and, consequently, the corresponding effort of understanding and extracting information that their reading could provide is reduced. (NR2-IT, NR1-SP).
- It is also noted that demands on reasoning are sometimes absent in experimental work (NR3-FR, NR3-IT), being reduced to the simple verification of previously taught laws. Insufficient place is given over to the goals of reasoned experimental practice in the search for coherence.
- Tasks to be carried out are limited to copying data, not as a way of building certain concepts (NR3-It), but as the simple performance of an experiment without reflection on the data involved (NR3-FR). Episodes of data dictation, instead of proposing data-gathering, have been also observed (NR3-IT); furthermore, observation and drawing are emphasised to the consequent detriment of argumentation. (NR3-FR).
- Within the same heading, we can include turning an exercise addressed at eliciting students’ previous ideas into a question simply asked to draw students’ attention to a given issue (NR3-IT,

NR1-SP). Proposed experimental predictions were sometimes changed to mere questions to be completed on a worksheet (NR1-SP), or alternatively, were reduced to the role of motivation (in order to encourage "a discovery activity") (NR3-IT), and the cycles of asking for predictions/experimentation/ (PEC cycle) were therefore ruled out (NR3-FR, NR3-IT).

- Finally, although some teachers actually acknowledge that students' previous ideas and spontaneous statements about scientific concepts are relevant, they do not take advantage of this in order to build knowledge. Thus, for instance, when students do come up with spontaneous conceptions in experimental situations, teacher avoid discussing them (NR2-IT, NR1-SP) as if the verification of a given principle (e.g. the Second Law of Dynamics) is in itself enough to eliminate students' conceptual difficulties.

To sum up, it can be said that, when faced with innovative tasks, there is a widespread tendency to place poor cognitive demands on students.

8.4.4. Reducing the scope of activities

Several situations in which teachers tend to limit the scope of the proposed task are described by the research teams. This tendency occurs irrespective of the targeted students.
Reduction of the scope of activities can be seen in the examples below:

- It has been observed that teachers revert the way in which the simulation programme is used. In this sense, an exercise originally consisting of looking for an unknown answer by attributing values to variables is transformed into an exercise of searching values for variables that provoke the obtaining of a fixed answer. (NR1-UK).

- When using images to tackle certain exercises proposed in the educational sequence, some teachers are only interested in specific aspects (i.e. with flow diagrams, students are required to focus on numerical calculations of efficiency). Additional tasks associated with the design of images addressed to concept representation are dismissed. (NR2-SP).

- Similarly, MBL is reductively used mainly as a lab tool, facilitating the easy performance of a great number of experiments, or as a motivating resource. Consequently, only some of the MBL advantages are taken into account (NR3-IT, NR1-SP).

- Graph analysis is also limited when unexpected traces of a graph from a real phenomenon are set aside. Instead, attention is drawn to integrating different ways of describing real/ non-ideal physical phenomena (NR3-IT). Attention is not paid to integrating different ways of describing a physical phenomenon (NR3-IT), cutting the "irregular" parts of a given graph without providing any justification. These parts are simply taken to be computer handling or instrumental errors found in devices when data gathering (NR1-SP, NR1-IT), thus neglecting the physical aspects detectable only through real-time experiments. Teachers may even go as far as claiming that a clearly irregular graph is actually regular in order to avoid the need for explanations of a greater range (for instance on friction).

- When certain relevant graphs are not drawn, students cannot establish the necessary comparison between experiments, which means that the scope of activities in the lab is reduced (NR2-It).

- The proposed modification of settings as a means of getting different graphical representations for data using MBL or CBL technology is transformed into data gathering, having only a single graph (NR1-IT, NR1-SP). In other words, the chance is lost of analysing that which can be variable and that which is permanent on a screen graph.

- Some teachers have expressed their willingness to move from using software simulation in a free and non-guided way to using MBL or CBL equipment, arguing that this will allow them to "achieve better control" (NR1-NO). It would seem that the boundaries of guided experiments makes them feel more comfortable.
- There have been some occasions when science courses have been used to teach how a PC works (NR1-IT) or to teach how specific software is conceived. Thus, for instance, an activity with

modelling software originally intended for learning Physics was transformed into an activity to learn how modelling runs, relying on a previous knowledge of Physics (NR1-UK). This means that an IT tool is used to learn how the tool itself works, taking advantage of some prior knowledge of a given scientific concept instead of using this Computer Tool to learn this very scientific concept.

- From this perspective of reduction, experimental work can be planned regardless of its goals, and can be restricted to the use of a specific device to carry out particular tasks (NR3-FR). Given this view, teachers can skip activities if they are considered too complex or demanding (NR3-FR, NR1-SP, NR3-IT).

Work in the lab is pursued in a way that seems to be consistent with the following view: seeing is sufficient for understanding, see what I want you to see, and a phenomenon (but one only) is embodied in a given device (NR3-3FR). This is also observed in the cross-comparison of data gathered by the Italian and Spanish research teams (RW3). Some of the trends in 7.3 summarised in RW3 can be interpreted as a way of simplifying the complexity of interpreting experiments.

Demand reduction sometimes consists of decreasing the amount of work involved in preparing teachers' own classes in which computer tools are used. In this respect, it has been shown that, when choosing between spreadsheets and devoted educational software, teachers prefer the latter, even if it turns out to be less transparent and productive in educational terms. In contrast, spreadsheets are more demanding in terms of their use and preparation. (NR1-NO).

Irrespective of interpretations and justifications that we can make of the above, observation of teachers' performance with respect to innovations in different settings and conditions has led to the conclusion that the scope of their proposed activities is reduced.

8.4.5. Switching the new proposal to different tasks

Teachers involved in this research seem to master the situation in such a way that classes are directed in accordance with teachers' own criteria. This implies a teacher reorientation of the goals planned for a certain task. Changes sometimes result in highly productive and creative tasks. However, changes are susceptible to giving way to activities different from those planned, that is, to activities having goals different to those that have been designed. And this activity may be more or less interesting, but it brings different objectives in its wake

- MBL technology for real time experiments has been used to analyse what is meant by measurement, or to teach mathematics in order to revise certain geometrical concepts (such as the Cartesian plane) (NR1-IT). MBL is not always used to analyse real phenomena but sometimes simply to obtain graphs of ideal phenomena, in spite of certain 'imprecisions' (NR1-IT).

- Additionally, an exercise consisting of elaborating working patterns (such as building a model for modelling software) is turned into putting previously built patterns into practice (i.e.: running modelling), the justification being that this is learned through practice: "Learning by Doing" (NR1-UK).

- From this biased view of innovation, it has also been possible to see that teachers' questions aimed at eliciting students' spontaneous conceptions turn out to be simple class questions which are corrected as mistakes (NR3-IT), or are simply unnoticed (NR1-SP).

- Furthermore, it was observed in the lab work for certain classes that only a few students actually gathered experimental data, whilst their classmates were mere onlookers, and were told which measurements were to be used for the worksheet tasks (NR1-IT, NR3-IT).

- Furthermore, instead of using real-time experiments to assess the plausibility of a given law, students are sometimes asked to solve numeric verification exercises (NR1-IT).

- When using MBL, experimental graphs are described as if they were ideal and perfect, teachers change the new proposals (using RT graphs together with their particularities) to different tasks (they continue using the graphs as if they were common textbook graphs). (NR2-It)

- Rather than being concerned with students' being able to build a model from experience, teachers get students to collect data and obtain graphs in real time, interpreting what appears on screen as a if it were the result of a mathematical function that has been "accomplished". Thus, a model is proved true or correct simply because it is accounted for by the data.

- Students do not benefit from the possibilities of modifying the settings associated with a graphical representation. Rather, they are asked to come up with a single graph instead of multiple representations (NR1-IT), the main goal being to save the work onto a floppy disk (NR1-SP).

- Analyses of graphical representation concerning the evolution of Physical phenomena are transformed into geometrical descriptions of graphical lines, where their physical meaning is lost (NR1-SP).

- Content selection or contents relevance is also occasionally modified. For instance, a global lack of attention paid by teachers to the Friction section has been observed (NR3-IT).

The specific cases highlighted here seem to provide evidence that, when dealing with non-assimilated innovations, a transformation trend operates switching the new proposals to different tasks.

8.4.6. Reducing the quality of interactions in the classroom

From a constructivist point of view, we believe that student discussions contribute to the personal and social construction of knowledge and teachers have often therefore been encouraged to propose discussion in class sessions (i.e. by means of PEC cycles). However, it seems that the reasons for this proposal have not been sufficiently explained or, alternatively, that they have not been fully comprehended, as observed teachers have often failed to take them into account. Changing traditional students' tasks throughout science classes seems to be fraught with problems.

- The approach to experimental work is altered when, instead of giving relevance to the interaction between students, this is transformed into a mere activity of data manipulation and data gathering throughout all lab work time. (NR1-SP).
- It seems as if there is a general understanding that "experiments speak for themselves" (NR3-FR, RW3).
- Thus, exercises about tracing the predicted graphs for the evolution of a phenomenon, and discussing its foreseen shape, are transformed into mere exercises of tracing graphs, which are not then further discussed in any general debate. (NR1-SP). It would appear that simply observing the computer screen or blackboard design should somehow already provide the answer to whether or not a prediction is correct. Time originally intended for discussing experimental data and graphs turns out to be entirely devoted to manipulation activities. Students do not therefore take advantage of the time saved in gathering data when using new technologies such as MBL or CBL in the lab sessions.
- Data are not discussed in the laboratory space, nor do students work with them. [The question arises, at this point, as to whether such functions are related to the lab or whether there is a general trend to assigning "a specific action to a specific place" (NR1-SP).
- It has also been observed that teachers ask students to fill in the worksheets and consciously choose not to pause over the difficulties they have expressed, but to postpone the discussion until after they completed the work at home (NR1-SP, NR3-IT). However, the eventual discussion was sometimes never forthcoming (NR3-IT), due to lack of time (NR-3 UK), or was only addressed to correlation among variables, without encouraging any discussion about the physical meaning of students' working data (NR3-IT).
- It has been observed that any work in small groups within the class has been ruled out (NR1-SP), and also that the functions assigned to groups are only those of noting down exercises or completing worksheets, rather than debating certain questions. (NR1-SP).
- Cases have also been found in which questions of the experimental scripts to be discussed in small groups were transformed into teachers' rhetorical questions, answered by themselves (NR1-SP). As a result, focus on teachers' personal preferences prevail over students' expected comments on the topic.

In all these cases, the anticipated quality of interaction among students or between students and the teacher has been reduced.

8.4.7. Reducing language refinement

Inaccurate use of language has frequently been observed. This ranges from teachers who argue in favour of an inaccurate use of language on timesaving grounds to teachers who showed little concern for this question in the various tasks undertaken. Whatever the reason, we can affirm that a general trend towards reducing anticipated care in wording has been observed, possibly leading to conceptual misunderstanding.

- Words such as temperature, heat and energy have been used without discrimination (NR3-SP). The same applies to s(t) and trajectory (NR3-IT).
- Furthermore, "energy is transferred in order for work/a job to be done" is changed into "energy is needed to get jobs done"; this implies a return to the traditional view of energy that it was intended to replace. It is also said, for example, that it is a simple "issue of language" (NR3-UK) to talk of "less useful forms of energy [being] what you produce, [though] not desirable".
- Energy degradation is expressed as non-transformable energy, as heating, as energy dispersion, as a change of energy form, as opposite to energy conservation, etc. 'Forms of energy' was used by all the teachers observed who taught the Energy topic both in the UK and in Spain, in spite of the fact that the documentation (books, booklets etc.) did not contain the expression. (NR3-UK, NR3-SP).
- The expression "energy transformed" is changed to "energy transferred", without the change implying a modification of the significance of transfer to that of transform. This can therefore give rise to statements such as "energy is transferred to motion energy and heating energy". The designers' intention is altered when a conceptual problem is changed into an issue of language.
- In the same light, a teacher talks about the "colour of the object" rather than associating light received by the visual system with perceived colour (NR3-FR).
- In proposals where particular attention is drawn to the issue of language (there were exercises especially intended to help establish a bridge between scientific language and everyday language) it has been noticed that teachers concern is expressed at the beginning of the class. However, shortly after the start of the session, terms are again used in a confused manner (NR3-SP). Thus within the same session teachers change from "you should not say that energy is lost, but that energy has been transferred within the environment" into "energy has been lost as heat".
- Sometimes, new terms are believed to be both too troublesome for students and to belong to higher levels. Thus, for instance, it has been stated that the concept of energy transfer is only appropriate to mature students as this concept is "tied up with waves and particles". Or "it is not necessary to introduce internal energy at secondary school, given the concept's complexity and because the unnecessary refinement regarding the concept is not relevant to school level".

Not only has an inappropriate use of oral language been observed, but this is also true of visual language. This is the case, for instance,

- When a diagram signifying concentration of energy turns into another diagram that they call an energy difference diagram (NR2-UK).
- When using MBL, the opportunity to show the relationship between abstract graphical representation and perception is disregarded (NR3-IT)
- When in the study of Colour, the conventions of the picture (image conventions) are an oversight, meaning that students may encounter conceptual difficulties due to an inaccurate use of visual language (NR2-FR).
- When RT graphs are not optimised, the opportunity to exploit the elements of the related visual language therefore being lost.
- When a clear distinction between the different functions of a straight line (representing a border line or a path of light) is not established (NR3-FR)
- When the difference between graphs corresponding to mathematical functions and graphs corresponding to real phenomena is not clearly shown, teachers lose the chance to teach how to discriminate among graphical languages. As a result, graphs not coincident with the "ideal case" are either reduced to such a representation (although observation yields a different interpretation) or "irregular" parts are excluded from the analysis, as they do not fit a given mathematical model.

- when the lines corresponding to the environment system symbol are turned into physical system boundaries, that is attributing a physical reality of the represented concept to a spatial site (NR2-SP)
- when a proposed symbol is used, losing its associated meaning (flux diagram) or is simply not used, since “it is not seen” (as images do not convey related concepts by themselves) (NR2-SP).
- when an image corresponding to a symbol for a new concept (or a concept approached in an unusual way) is distorted by altering its features, or is deprived of the notion of communication through disregarding the meaning of the lines. (NR2-SP).
- when, in flow diagram representations, where an arrow area represents the amount of energy transferred to the environment, images are transformed so that arrows are converted to vectors, no longer transmitting the concept of quantification related with energy conservation (NR2-SP)
- when symbols are regarded as representations of material objects, such as ray paths (NR3-FR) or energy (NR3-SP).

In short, the lack of attention drawn to aspects of visual language concerning proposed images affects both students’ capability to learn visual language and their possibility of understanding represented concepts.

Language inaccuracies, as the previous comments have highlighted, are associated with conceptual misunderstanding, which appear to be so firmly rooted that they could only be reversed if there is a better understanding of the root concepts and an accurate analysis of the meanings conveyed by the poor language used. When applied to visual language this can be stated from the following observed fact: courses (in Colour) aimed at improving the chaining of concepts and the coherence of the global exposition have led teachers to tackle images from a new perspective: more critical, with increased vigilance of the design of the image. In those cases, it has been realised that teachers discover missing elements and show concern about problems that may arise from symbol similarity (RW3, NR3-FR).

8.4.8. Changing the teachers’ assigned role

An unexpected trend found by different research teams has been that of the change in teachers’ roles when faced with innovative proposals in different fields:

- Changes have been observed in the role of answering questions. In some cases, if teachers are uncertain about a given answer, questions are passed on to students. Teachers turn down questions posed by their students either by means of returning the question or by reformulating it. The leading role is inverted.

- When there is new computer equipment or a new computer application, teachers do not explain how it works; this task is passed on to the most skilful students who manage to display it to their peers.

- As far as RT graphs are concerned, some teachers allow students at the keyboard to decide how to optimise a given image for themselves, providing no correction whatsoever when students are not doing the optimisation task successfully. This is an unexpected change in teachers’ role, since it effectively means that responsibility, with regard to visual language, is neglected.

- Some teachers have shown themselves to be more interested in scientific concepts themselves than in their students’ learning process. Student errors are seen merely as the incorrect outcome, without any analysis being attempted of the underlying reasons explaining why the student has written or drawn something incorrectly. For instance, teachers do not try to explain (or simply do not realise) that students have not distinguished space points from graphical points, resulting in an incorrectly predicted graph. It would appear that certain teachers only give importance to the incorrectness of the outcome.

- A further trend, perhaps related to the previous point, is that of only an over-preoccupation with students’ state of mind. When students work in class, teachers are mainly concerned with maintaining a quiet and calm course group and encouraging their students to do well, but they do not attempt to understand the causes underlying the failure in their students' scientific reasoning (NR1 SP).

- Teachers' roles also change when they are not those who decide class activities. (NR1-NO). When students are interested in a given activity, the original plan is altered. Teachers are flexible, and tend to accept students' proposals, thereby putting aside the expected goals of the originally planned proposal.

Overall, it can be concluded that the traditional teachers' role (i.e. that of being the only authority in class who decides what to do at each step, and whose most relevant role is to assess the answers, proposals and questions made) has been altered to a certain extent. However, it seems that these changes could be related to a lack of self-confidence more than to the acknowledgement of the new innovative roles being assigned to the teacher.

8.4.9. Adjusting to contextual circumstances

The use of different innovations in science courses leads teachers (and sometimes the school itself) to adapt to a new situation. Some teachers analysed by the different research teams have altered the proposed activities in several ways:

· To comply with time constrictions.
Many times teachers have explained their performance in class on the ground of time pressure. Some teachers leave out parts of the proposed sequence in order to "go faster". They fail to plan post-activity discussion due to lack of time. An activity is ruled out or students are told to do it at home if it is believed to be repetitive. Furthermore, they tolerate situations in which only some students collect data from the computer, or tell the class to complete worksheets if the allocated computer-room time has run out.

Some teachers refuse to use IT tools in courses evaluated by external examinations, asserting that there is insufficient time (NR1 NO). IT tools are thus considered highly interesting devices, yet ones that limit the rhythm of work.

· Compliance with constrictions concerning the use of space also affects teachers' performance of new proposals.
In order to have access to the computer room or to have computer equipment in the lab, some teachers have to undertake a wide variety of 'manoeuvres'.
The computer room has to be booked in advance in order to ensure full access throughout the pre-established time slot. Additionally, activities to be done in the computer room have to be planned in advance, since it is not always possible to discuss results, given that other groups sometimes share the computer room. This has led to splitting course groups and to establishing turns for running the desired software. (NR1-IT)

Access to the central computer is not guaranteed to all students, so there is some sort of space constriction to be taken into account. Some students are only able to watch the activity of other classmates (or even the teacher) that is running on the central screen, and then load the data collected in class onto a portable computer or, simply load the complete software (NR1-NO), so these objective circumstances have influenced the efficacy of the activities being carried out. If teachers do not have sufficient sensitivity to this issue, restrictions of space can mean that students fail to see the screen on which the graph is being drawn, in real time, of the phenomena/process taking place. An inadequate placement of the central screen would make it difficult or impossible for some students to observe the graph, and this in effect would entirely undermine the rationale of the MBL equipment (real-time experiments).

· To comply with their students' demands
Teachers' plans are usually adapted by taking into account the students' learning process as well as curricular requirements/demands/concerns/considerations from previous courses.
In a more or less conscious or unconscious way, teachers have expressed concern for their students' conditions. Although there has been no planned action towards diversity, there is a tendency to look at students' class rhythm as expressed through questions, exercises or gesture. This has led to explanations and questioning being repeated, and to designing more "practical work" if this is

considered necessary. Teachers are even willing to change experimental conditions so that students attain a better visualisation of a given phenomenon, no matter how materialised a concept may then become. It has been observed that some teachers are able to modify an activity without goals being altered (NR3-It. NR-1-It) in order to provide the activity in question with a more entertaining character.
When implementing new sequences, teachers sometimes "gradually work them in ", unsystematically choosing new material for introducing these new selections into the regular school curriculum. What is considered to be missing in the proposal is completed in order to comply with the official curriculum. (NR3-UK). If teachers wish to assume the use of IT tools in science classes, they integrate them into the teaching process, select appropriate phenomena to be analysed through such tools and even plan a sequence of lessons in order to use the Computer Tool in a series of steps.
It appears that this context adjustment in the end leads to more flexibility, permissively and to a lack of rigidity with respect to the distribution of space and time. Moreover, it allows for a distinguishing of what is transient and what is permanent, together with clear-cut criteria about what goals are worth fighting for in order to be attained.

8.4.10. Adjusting to teachers' personal habits

A general trend has been observed, which probably could not have been otherwise, for teachers to adjust activities to their traditional working habits. This may lead to difficulties when implementing innovations as it can give way to a certain reluctance or to conceptual and procedural alterations when adding new information to previous teaching content.
Teachers have been found who describes the traditional strategy of teaching concepts in a declarative way as "the" most efficient way for students to learn.
In the same way, those teachers who are accustomed to introducing concepts through starting with the ideal phenomenon maintain this approach when asked to move “from real to ideal phenomenon”.
Something similar happens with the word/concept ‘filter’. A filter is introduced only as an object allowing light to pass selectively, forgetting the phenomenon of diffusing light; questions are therefore focused on colour and not on luminosity and visibility (NR3-FR).
Similarly, light rays are presented as materialised rather than nonmaterial objects.
When referring to vision, teachers talk about light propagation without pointing out the eye’s receiver role (RW3).
Teachers maintain their old routine without paying attention to the "critical details" specified in the new proposal (NR3-FR).

In the use of Computer Tools, teachers’ development can be traced back (from skeptisism to absolute enthusiasm, ending with moderate confidence) and it is interesting to observe that each one of these gives way to different student activities in classroom.

8.5. Interpretative frameworks to explain the results and Future Implications

The methodology used has allowed to answered the research question posed by this workpackage 4:

> *Can general trends be inferred in the transformation undergone by teachers when facing different curricular innovations?*

and to group results from the different Phases in order to achieve greater generalisation and conceptual coherency.

Certain general trends from the teachers' sample analysed in our Project have been possible to establish. These trends account for teacher behaviour when faced with the innovations proposed by the research groups involved in the STTIS project. These trends are as follows:

- Fragmenting holistic views or approaches
- Modifying small but crucial features
- Reducing the cognitive demands placed on students
- Reducing the scope of activities
- Switching the new proposals to different tasks
- Reducing the quality of classroom interaction
- Reducing language refinement
- Changing the teachers' assigned role
- Adjusting to contextual circumstances
- Adjusting to teachers' personal habits

From a pragmatic point of view and in accordance with the data analysed, it might be said that teachers facing innovations similar to those proposed in the STTIS project will probably show trends in line with those described by the headings listed at the start of this section.

Interpretative aspects have intentionally not been addressed, since our aim was to remain as close as possible to the empirical data, thereby facilitating the potential users of this work with an approach that emphasises teaching reality, i.e., access to current behaviour observed in teachers when implementing innovative proposals in their classes.

8.5.1. Implications for Teacher Education

These results seem to be relevant to teacher training. We believe that the trends shown in this study might be a good starting point for those teacher trainers interested in preparing teachers to take up curricular innovation. Our work, in this sense, provides descriptions of certain behavioural trends whose undesired effects could be then anticipated and/or avoided.

At this point, and bearing practical goals in mind, we think that some interpretative remarks on the results obtained should be made. It may help teacher trainers to broaden their views when explaining teacher trends in implementing innovations. Specifically, we would draw attention to different interpretative frameworks found in the literature concerning teacher thinking.

When referring to the related literature, we find several frameworks through which some of the above-mentioned trends can be explained.

8.5.1.1. Issues related to knowledge based systems and teachers' belief systems with regard to subject matter content

This is the most widely studied aspect. Research attributes certain teacher behaviour to "inadequate" disciplinary knowledge (Cochran and Jones 1998), be this a superficial level of organisation (Tamir 1992), lack of coherence (Pro 1998), weak understanding of specific content (Shulman 1987, Tüllberg, Strömdahl and Lybeck 1994, Parker and Heywood 2000), rigidity of content knowledge (Moje 1995), common-sense understanding of scientific concepts (Vicentini 1999, Furio and Guisasola 1998, De Manuel and Jimenez, 2000); "inadequate" belief systems with respect to the nature of disciplinary knowledge, namely, the epistemology of science and the ontology of scientific entities (Gutierrez and Pinto 2000, Zuzovsky 1994, Lederman 1992, Pomeroy 1993, Désautels and Larochelle 1998)

8.5.1.2. Issues related to teachers' beliefs about their own identity and appraisal

Teacher identity, personally and socially built, has largely remained steady up to the present time. Roles assigned by society and personally assumed by teachers are the following, according to Van den Akken: information transmission; leading students' actions; knowledge of fixed and precise contents which are capable of being attained by students and contained in the textbook; responsibility for always providing the right answer to students' questions. Taking into account curricular innovations designed in the light of educational research, teachers are provided with new roles (that of facilitating students with the independent acquisition of new information; that of suggesting new activities through which students can independently build a knowledge domain; that of providing students with a multiple and varied range of materials, and particularly that of using facilities from IT technology). Given this view, it is easy to understand that teachers do not appear confident with respect to mastering knowledge and its classroom application, and that they are concerned that society will not comprehend their new role, for which they wish to be respected. As Black and Atkin say:

"How much can teachers dare to risk of their professional persona, that sense of their own identity in which both, institutional authority and expertise as physicist, mathematician or whatever play so large part? … For what can they be held accountable? Where will they find a satisfactory alternative to the security of the text? If not in direct leadership in the classroom, then wherein lies their expertise?" (Black and Atkin 1996 p 121).

Even if teachers participating in the STTIS project are motivated and willing to apply innovations in their science courses, it is by no means clear that they have reached the stage "of reconstructing their own view for themselves as what it means to be a teacher of science" [according to the new assigned role] (Bell 1998 p. 684).

8.5.1.3. Issues related to teachers' beliefs about teaching and learning

According to the available literature, this is probably one of the most studied issues, together 8.5.1.1. Teachers' beliefs about teaching and learning influence the way they act in their classrooms and establish their interaction with their students (Cornet et al 1990, Brickhouse and Bodner 1992). The "ideology of teaching" (Geddis 1991) expressed by the teacher is some time very far from current constructivist approaches. Their overall teaching strategy mirrors that they encountered when being taught (Huibregtse et al. 1994). Furthermore, they maintain that efficient learning can only be achieved if teachers directly transmit knowledge to their students. This is the case even when teachers "acknowledge" the relevance of constructivist views on science teaching/learning (Johnston 1991).

Moreover, according to de Jong et al. (1998) teachers believe that scientific knowledge is not problematic and that its learning mainly depends on student motivation; that lab work is valued because it keeps students active, not because it promotes learning; that learning is more efficient if rules and quick explanations are given, since facilitates time saving and maintains students' attention.

8.5.1.4. Issues related to teachers' beliefs about contextual constraints (school, classroom, syllabus, exams, etc.)

In the literature we also find teachers' beliefs about the constraints imposed by the context or "climate" of the school and classroom, about expectancies created by covering the syllabus or preparing their students for exams, or for the next level of schooling.

According to van den Akker, probably the most difficult dilemma for a teacher is that of covering content versus depth of understanding, which leads to the experience of tension vis-à-vis their beliefs and values regarding their classroom role (van den Akker 1998 p. 435). This issue is also addressed by Bell (1998 p. 687), who speaks about teachers' concerns regarding their responsibility to students, parents, employers and the government to ensure that the prescribed curriculum is covered. This author also points out that new teaching activity can induce negative feelings in some teachers if such activity does not result in well-filled student notebooks. These concerns can be viewed as cultural constraints, that is, the traditional culture of schools, inspectors, parents, etc.

When teachers are worried about classroom control, they occasionally adopt an authoritative position as a consequence. This "pedagogical context" means that, on many occasions, they do not overtly explain the aim of the teaching sequence or the intended function that is actually being undertaken in the overall instruction process. Such situations leave the students dependent on their teachers in the process of learning, and thereby favour the learning of disconnected concepts, leaving aside the search for integration and coherence (Geddis 1991 p 173).

It is therefore easy to perceive that the different frameworks previously presented are possibly deeply connected, and are irreducible only in an analytical way to one other; it can also be said that such frameworks are distinguishable only by placing borders around the scope of the various research activities undertaken, or are valid only for the sake of following different traditions of research (i.e. cognitive science, social constructivist, cultural anthropologist, teacher thinking, etc.). Whatever the case, the frameworks we have described were also chosen for practical reasons, bearing in mind the current state of the art and the possibility of offering a sense of coherence to our findings.

The different trends described and the possible explanations given by these theoretical frameworks can help broaden teacher trainer perspectives when seeking pragmatic and interpretative references in their professional task.

8.6. Observations addressed to teacher trainers

In the figure below, we present a number of remarks to teacher trainers. Furthermore, we illustrate those relationships that can be established between the inferred trends and the interpretative frameworks. The purpose of the STTIS project (1998) is that its results be applied to teaching practice, as is the aim of the following Observations for Teacher Trainers. That is, it aims to provide certain hints, capable of being validated by future research, in order to achieve the successful implementation of innovation.

Inferred trends

Fragmenting holistic views or the holistic approaches

Modifying small but crucial features

Reducing cognitive demands on the students

Reducing the scope of activities

Switching the new proposals to different tasks

Reducing the quality of interactions in the classroom

Reducing language refinement

Changing the teachersÕ assigned role

Adjusting to contextual circumstances

Adjusting to teacher's personal habits

Interpretative frameworks:

TeachersÕ knowledge-based and beliefs systems, related to their subject matter content.

Teachers' beliefs about their own identity and appraisal

Teachers' beliefs about teaching and learning

Teachers' beliefs about contextual constrains (school, classroom, syllabus, exams, etc)

Observations for Teacher trainers

Stress the relevance of giving an holistic view of topics and their related concepts; associate what is currently dealt with top revious material; make it clear what is offered by a given set of activities or by different parts of an activity or exercise; promote the understanding of the links between components of a computer tool; integrates IT in a set of activities within a teaching sequence; present images as a whole where its elements make the message coherent

Make teachers aware of the relevance of studentsÕ cognitive development; be accustomed to providing reasons, justify points of view; avoid limiting the demands only to descriptions, classifications or memory techniques; emphasise the importance of asking for predictions i.e. in prediction-experiment-debate cycles; suggest open question; pay attention to studentsÕ previous ideas in order to promote learning.

Emphasise the need to take full advantage of a given activity both from the perspective of those contents that are linked and the skills and attitudes that can be promoted. Encourage students to raise questions with unknown answers, to propose their own new activities, to suggest new experiences, etc.

Provide teachersÕ with the necessary tools in order to decide what goals are to be achieved by each proposed task, and throughout the course. Advice about the importance of the critical details of the proposed sequences. Remark on the necessity of distinguishing between the different nature of concepts arising from different subject matters or from different contexts.

Emphasise the relevance of interaction between students themselves and between students and teachers to promote the personal and social construction of knowledge

Emphasise the need to be extremely careful with language (oral, written, visual) on the basis of conceptual accuracy. This means

á helping to express what is referred to everyday language in scientific terms

· be cautious in interpreting and drawing graphs, schemes, figures, etc.

· analysing and understanding new scientific terms before deciding whether this can be accepted or rejected as teaching contents.

Promote the reflection about the teachersÕ role of facilitating conditions for studentsÕ personal growth. Advice about neglecting teachersÕ leadership when they abandon their responsibility of managing and controlling the class on the grounds of favoring studentsÕ freedom.

Support those teachers who do not feel confident in the newly assigned roles, and provide reasons to stress that this does not necessarily result in diminishing their authority.

Taking into account curricular constraints, providing elements to distinguish what is essential from what is anecdotal; making teachers aware of the adjustments needed by each group, and the advisability of analysing rejected goals when there are time or space constrictions, and acting accordingly.

Promote discussion about teachersÕ own routines in order that the proposed changes can not be interpreted as a dismissal of their teaching professional tasks. Provide thorough justifications in favour of innovations and explain why it is advisable to change what has been done so far, if necessary, to improve the process of student learning.

TEACHER TRAINING MATERIALS

Preparing training materials based in research results

9. Workpackage 5. Teacher training materials favouring the take-up of innovations

This chapter had been written on the basis of the transversal report:: *Teacher training materials favouring the take-up of innovations. RW5*,. Sassi, E., Monroy, G., Testa, I., Ametller, J., Andresen. O., Balzano, E., Boohan., R., Chauvet, F., Colin, P., Couso, D., Giberti, G., Gutierrez., R., Hirn-Chaine, C., Ogborn, J., Pintó, R., Quale, A., Rebmann, G., Stylianidou, F., Viennot, L.. 2000. (http://blues.uab.es/~idmc42/document/index.html)

9.1. Training materials

The specific STTIS results regarding the transformations made by teachers in current class implementation of innovations, as well, many previous results of science education research studies about teacher training and those underlying the studied innovations (e.g. educational potential of informatic tools, students' common learning difficulties, etc.) have contributed to the elaboration of materials for teacher trainers that constitute the WP5.

Addressing students' common learning difficulties is now acknowledged as necessary in a teacher education programme, given the role the difficulties play in the learning process and consequently in any teaching strategy. However, addressing teachers' common problems in classroom adoption and implementation of an innovation is not yet recognised as being equally significant, nor is it practised in standard teacher education programmes. The training materials presented for WP5 are aimed at addressing several aspects of teachers' common problems in taking up innovations of different types, drawing on results of the STTIS research studies.

The rationale of the work done in the framework of WP5 is strictly linked with the answers found to the research questions answered in the WP4. There it has been evidenced, in the previous chapter, that several types of interpretations and/or transformations of the studied innovations have been made by teachers, some resonating with the didactic intentions and the potentialities of the innovations, and some not. Therefore the rationale of the training materials and the example training sessions support the view that reflection on interpretations and transformations made by teachers when adopting an educational innovation is a crucial part of teacher training aimed at favouring the take-up of innovations.
WP5 is also intended as a product aimed at highlighting the importance of this theme in teacher education, through a set of concrete examples.

9.2. Global rationale of the training materials

Two types of input have contributed to the rationale of the materials prepared for WP5. One derives from the previous results of science education research studies about teacher training and those underlying the studied innovations (e.g. educational potential of informatic tools, students' common learning difficulties, etc.). The other draws on the specific STTIS results regarding the transformations made by teachers in current class implementation of innovations.

Addressing students' common learning difficulties is now acknowledged as necessary in a teacher education programme, given the role the difficulties play in the learning process and consequently in any teaching strategy. However, addressing teachers' common problems in classroom adoption and implementation of an innovation is not yet recognised as being equally significant, nor is it practised in standard teacher education programmes. The training materials presented here are aimed at addressing several aspects of teachers' common problems in taking up innovations of different types, drawing on results of the STTIS research studies.

The rationale of the work done in the framework of WP5 is strictly linked with the answers found to the research questions quoted in Section 1. These show that several types of interpretations and/or transformations of the studied innovations have been made by teachers, some resonating with the didactic intentions and the potentialities of the innovations, and some not. Therefore the rationale of the training materials and the example training sessions support the view that reflection on

interpretations and transformations made by teachers when adopting an educational innovation is a crucial part of teacher training aimed at favouring the take-up of innovations.
WP5 is also intended as a product aimed at highlighting the importance of this theme in teacher education, through a set of concrete examples.

The innovations studied in STTIS have different characteristics: computer based approaches such as computer modelling/simulation and real-time experiments; visual communication through various types of images; new teaching approaches accepted by national curricula or tested on a local scale.
Each set of materials can be used by trainers as it is or to design and implement a personalised training initiative.

9.3. List of Workshops

The five European countries involved in the STTIS project have prepared for this work package the following eleven sets of training materials. For the sake of brevity, from now on, they are indicated as Workshops.

France

- F1) "Constructing a teacher training session about Light and Vision", refers to the French syllabus of optics for grade 8, a sequence of about 16 hours, specified in the official texts distributed nationally (BOEN 1992, MEN 1992).
- F2) "Constructing a teacher training session about colour", inspired by common views on the teaching learning process (Chauvet 1994, 1996a, 1996b, Viennot & Chauvet 1997).
- F3) "A teacher training workshop: teaching geometrical optics with computer simulation of ray diagram". The examples of the training have been performed with the programme ASOG (Atelier Schéma d'Optique Géométrique), a ToolBook application (in French) running on PC under Windows system, designed by one of the author (G. Rebmann) .

Italy

- I1) "Teaching kinematics" refers to teaching proposal "KIN: A proposal to teach kinematics in secondary school", designed by the Italian team; it is not part of the official curriculum, has been tested on a local scale.
- I2) "Teaching Real Time Experiments and Images", teaching approaches based on Real-Time lab-work and use of images of produced graphs. The used system is Microcomputer Based Laboratory (MBL).

Norway

- NO1) "Computer Simulation" addresses simulation of physical processes, through either dedicated software or the use of a spreadsheet.
- NO2) "Data Logging", hardware and software in physics lab work, using Microcomputer Based Laboratory (MBL) or Calculator Based Laboratory (CBL).

Spain

- S1) "Teaching about Energy Degradation" refers to "L'Energia", a teaching proposal designed by the Spanish team, for secondary school students, tested at local scale. It is not part of an official curriculum
- S2) "The use of images as a didactical tool" refers to images purposely designed by the Spanish team for the STTIS research study WP2.

UK

- UK1) "Training teachers for innovation: energy transfer and the direction of change", refers to: "Energy and transfer", Science National Curriculum (NC) for pupils of compulsory school age (5-16 years old) in England and Wales, and "Energy and change", (Boohan and Ogborn, 1996a; Boohan 1996a).
- UK2) "Training teachers for innovation: computer simulation and modelling", refers to use of computer modelling through use of spreadsheets in two contexts: "Electricity" and "Forces and motion".

9.4. The main features of the training materials

The proposed materials, centred on a Workshop, have as a main aim that of favouring the take-up of the addressed innovation; this is achieved, for example, by considering the scientific concepts associated with the innovation, the difficulties that may rise, the materials which are used in schools, how teachers can design materials and activities, and so on.

The main features of the training materials are outlined hereafter.

Audience
The materials have been designed and written with the trainers in mind.
Some of the workshops (F1) focus not just on a particular innovation but on the type of training itself.
In such cases, the materials are to be seen as a resource from which the trainers construct their own session. That is, some of the Workshops are proposed to provide examples adaptable to other innovations, in this sense, having a "prototypical" character.

Support
Specific examples of activities and instructions are presented to support the trainers. Style and content are different in the different workshops, but the purpose is the same.
Several indications on how to use the proposed materials, how to carry out the activities and which could be obstacles in the learning/teaching processes are present in the materials.

Research basis
The main STTIS research results have been transferred in the training materials, together with results from other studies. So the whole set of documents is a research based training proposal.

The STTIS research studies have focused the importance of transformations done by teachers when implementing an innovation in class, of factors that may influence the teachers actions, of addressing "critical details" for a successful innovation adoption. All Workshop materials refer to such results.
In S1, for example, the STTIS results are reported, among others, in the "Answers of the examples of activities".
In UK1 and UK2, there are activities focusing on understanding the factors influencing the innovation take-up and on transformations occurring in class practice.
In F2 the role played by the "critical details" is stressed:
In I1 attention is called on the transformations trends shown by teachers:

9.5. Cross comparing the materials

9.5.1. A common rationale

The training materials proposed by the partner countries refer to different innovations: some are Informatic Tool based approaches such as computer modelling, simulation and real–time experiments; some relate to visual communication implemented through various types of images; some propose new teaching strategies included in national curricula or tested on a smaller scale.
All materials, designed to favour the take-up by teachers of the innovations and their implementation in current class practice, refer to and share the same rationale.
The main features of the rationale are:

- the STTIS results as general transformations trends inferred in WP4, through the observation of teachers implementing the innovations in ordinary class-practice (results of work packages WP1, WP2, WP3), are used and reflected in the training proposals.
- The training activities are centred on critical analysis of teachers' typical actions to allow recognition of similarities and differences with individual trainees' situations. Activities easily transferable to class-work are proposed, in order to emphasise the experiential character of the training and to suggest hints for designing others.
- the proposed materials are all written with teacher trainers and trainers of serving teachers in mind; they are in the format of "prototypical" Workshops (WS)

This choice is aimed also at encouraging the trainers to design their own training initiatives. The example structures of the Workshops may be adapted to innovations other than the ones studied in STTIS.

9.5.2. Some variations

In the framework of a common rationale, the Workshops present some variations according to the specific innovation whose take-up they are aimed at favouring.
Examples are:

- *the amount of detailed instructions offered to the trainers*, both for planning and conducting the training activities.
There is a kind of a continuum, at one end the two Spain Workshops present very detailed suggestions for the activities to be performed, while at the other end the Norway WSs suggests very little and leave the choice to the trainers. The UK, France and Italy proposals are somewhere in between; detailed briefings, illustrative sequences and examples of WS conduction are suggested, aimed at orienteering the trainers.

- *the existence of an intermediate phase, between the first and second part of the WS*, in which the trainees are asked to perform an activity in their classes (or to describe a simulated one if they are not in-service teachers). This is what UK and Italy WSs propose; detailed feedback and discussion about the results of such activities takes place in the final session. In the case of Norway, if the trainers choose a two days duration of Workshop, a period of 1-2 months in between them is suggested to gain practical experience.
In the case of Spain and France workshops, the trainees are not requested to do such class activity; the trainers' feedback is about written proposals for students' tasks which have been prepared by the trainees during the WS. The feedback materials reflect features of the training rationale, e.g. in the case of France, the focus on a detailed analysis of "critical details".

- *the materials proposed for supporting the trainers.*
In the Spain case, research results about students and teachers conceptions also related with STTIS research, are presented, together with contents/sequence of the proposal l' "Energia", and suggestions for new approaches to teaching energy. In the Norway case some suggestions for appropriate experiments are given; in the Italy case summaries of research results, a catalogue of commented emblematic experiments, examples of trainees' simulated tasks and teachers' "Stories" (narrative of class observations plus interview quotes) are offered; in the France case research results about students' learning difficulties, emblematic view points of teachers and STTIS results about teachers transformations are presented. In the UK case plenty of resource materials, many examples of class activities, commented references to research results and detailed briefings for the trainers are proposed.

The variations present in the individual Workshops are also related to: content of addressed innovation; teacher training tradition of the partner country; aspects and factors which may influence positively the acceptance of the training.

- *the Workshops address a disciplinary content or an approach*
The take-up of an innovative approach is somewhat different from the take-up of an innovation aimed at teaching a specific disciplinary content. Internalising an approach entails broad acceptance of its rationale and also means becoming capable of implementing it in different contexts and situations and interpreting it in resonance with its didactic potentialities. Therefore the take-up is transversal with respect to contents, even though implementation of the approach and design of class activities calls for a specific content to be addressed.

- *the content addressed in the training is "new" from a didactic viewpoint*
The particular disciplinary content addressed in the Workshop influence some aspects of its structure. For example, in the case of Spain, Energy Degradation is a topic not traditionally taught; this is also the case for Energy and Change and Energy and Transfer (UK). When the content is "new" from a didactic viewpoint, a great effort is devoted, in the Workshop, to help the trainees familiarise with all

changes implied in adopting a different viewpoint and in acquiring the capabilities needed to successfully use it in the class-work.

- the innovation is recommended at a national level or is a local proposal

In those situations where the external conditions cause more constraints, as for instance in those partner countries where the curricula are decided by national authorities, the training focuses more on transformations done by teachers than on factors influencing the innovation take-up. This is the case of Italy, where (in most Secondary School classes) only two hours per week can be spent for physics in the framework of the national syllabus. The critical analysis of situations where colleague teachers, in current conditions have implemented the innovation, is a basic activity. A similar attitude characterises the Spain and France proposals; in the last case much attention is called upon the critical details influencing a successful take-up of the innovation.

The focus is different in the training proposals prepared by partner countries where the teachers have a much greater autonomy; in the case of UK, the main contextual factors within which teachers work are focused upon. The Norway proposal calls attention on severe time constraints, and lack of support from the final examination for the take-up of computer simulation.

- specific national realities as traditions of training programs or trainees' attitude with respect to training courses

In the case of Norway, teachers enjoy a considerable degree of autonomy in the teaching/learning process. Thus, in a training workshop any detailed instructions would quite likely be self-defeating and the trainees would have difficulties in accepting it. In the case of Italy, it is appropriate to propose the trainees more experimental activities than meta-discussions, and to call their attention on example difficulties in adopting the innovation. In the UK, there is a wide variety in the kinds of training for serving teachers; increasingly, effective training is seen as being centred on the school and adaptable to different local circumstances.

In the case of Spain it is usual that trainers adapt the proposed structure and materials to their schedule/circumstances. They expect many resources in order to adapt them. In training sessions trainees share their opinions and beliefs, the trainer being a discussant guiding toward the proposed aims.

Finally, the training materials prepared in the framework of WP5, form a *set of self-consistent proposals* characterised by a common rationale; namely the variations indicated above do form a synergic variety which can encourage the take-up of innovations differing both in the content addressed and the tools used.

The effort done in this work has been to design research-based examples of teacher training, aimed at fostering the complex process of taking up a didactic innovation through materials which can be used in many ways.

We think that the prepared materials can make a contribute to this aim at a European level.

GUIDELINES FOR POLICY-MAKERS

10. Workpackage 7: Guidelines for policy-makers

A concise presentation in terms of guidelines for policy-makers can be a useful way to communicate the results of an educational research program; the aim being to present suggestions for improving the design and implementation of teacher education programs and of didactic innovations. A work-package WP7, containing guidelines from results of the STTIS research project about educational innovations, is addressed to these goals. Here we summarise some of the recommendations of general validity at European level.

This chapter had been written on the basis of the report. *Guidelines for policy-makers of teacher training programs RW7*, 2000. Sassi, E., Ogborn, J., Pintó, R., Quale, A., Viennot, L. (http://blues.uab.es/~idmc42/document/index.html)

10.1.1. General recommendations

Internalising innovative approaches

The introduction and naturalisation of didactic innovations is a complex process. Innovations in science education are increasingly needed to foster greater scientific literacy of the citizen. They are inevitably transformed by teachers who not passively implement the innovations' didactic intentions; thus innovations need to be flexible and robust. All didactic innovations to be fully naturalised, i.e. to be thought and used as natural and appropriate strategies/tools for teaching/learning, go through a "metabolic process" that may be long. Internalising innovative approaches entails broad acceptance of their rationale and also means becoming capable of implementing them in different contexts and situations and interpreting them in resonance with their didactic intentions and potentialities. The take-up of the innovative rationale is transversal with respect to contents, even though implementation in class-work calls for a specific content to be addressed.

Appropriate teacher training programs

During the naturalisation process many changes of the innovations may occur since teachers adapt them to specific goals and objective circumstances. Teachers need positive assistance in coping with the transfer of innovations into actual class-work, since often this implies not minor changes in their role. In order to acquire the know-how needed for a successful adoption of innovations, teachers need to be supported in becoming well aware of why the innovations are proposed and of the problems encountered in traditional teaching approaches. Learning/teaching difficulties in science education are widespread and many have been thoroughly studied. In the current status of science education, still many problems are present and innovations may greatly help.
To favour the take-up of innovations, appropriate teacher training is a crucial element, even if this alone cannot guarantee successful innovation adoption by teachers. Thus policy-makers should trigger the implementations of appropriate teacher training programs, which greatly benefit from research-based recommendations.

Here some guidelines are presented, they are aimed at improving teacher training programs and at favouring the take-up of innovations. They refer to both the rationale of the training and to specific features of the training materials.

Innovations' take-up

The training design and materials should be prepared taking into account that innovations are easier to accept if: - they address curriculum areas not presently taught but which teachers would value. In many systems this would involve the development of new curricula so that work on these new areas would not be seen as distracting from the syllabus content; - they address those curriculum areas taught but where teachers believe that present methods are ineffective. Experimentation is more likely to be viewed as reasonable if what exists is felt not to be good; - they address also disciplinary contents teachers are well familiar with.

Transparency of reasons for innovations

The training should give grounded reasons for the proposed innovations, taking advantage of the science education (and related fields) research results, in order to improve acceptance of new approaches by teachers.

Effective integration of the "new" approaches with the "old"

The training should address explicitly and extensively how the "old" approaches need to be avoided, modified, integrated with the "new". The use of case studies is strongly recommended. Emphasis on problems deriving from traditional teaching is recommended, for instance through commented examples of both students' learning difficulties and inefficient teaching strategies.
Focus only on the "new" should be avoided; it is recommended to associate what is being and what was previously dealt with, and to explain and clarify the risk of conflating the "new" with the "old", which easily results in hypertrophy and/or incoherence of the teaching process.

Focus on holistic view

The training should focus on helping the teachers become aware of and grasp an holistic view of innovation: topics, concepts, approaches, etc... The aim is to avoid or minimise the tendency to fragment a whole into small unrelated pieces..
Emphasis on establishing links between activities, questions, specific episodes, different levels of language, etc, is highly recommended, for instance through analysis of examples and tasks about them.

Linking innovation rationale and critical details

The critical details of an innovative approach, that may deeply affect its impact, are also the most difficult to communicate to teachers.
The training should explicitly explain, show and illustrate, through real cases, that without appropriate detailed actions the innovative effects are easily reduced or nullified.
Special focus is needed on increasing teachers' awareness about careful planning of the cognitive dimensions of class activities as well as of their practical aspects.

Attention to language (oral, written, visual)

The training should extensively explain and show the need to be extremely careful with all types of used language. For instance, this implies: - help to word in scientific terms what is expressed in everyday language, eliciting and overcoming possible conflicts; - attentive care in drawing, reading and interpreting graphs, schemas, diagrams, etc.; - analysis of the understanding of new scientific concepts proposed, to verify their correct adoption
It is also recommended the analysis of teaching materials (texts, images, activities, worksheets, etc.) which may reinforce students' previous erroneous conceptions and learning difficulties. Special attention should be paid to encourage students to interact verbally about the proposed tasks.

Reflections about possible transforming trends in taking up innovations

The training should call attention upon the most common transformations and limited interpretations of innovations done by teachers in implementing innovations in current class-work, as, for instance, the transformations trends listed above. Analysis of examples and case studies is recommended, together with focus on practice, discussing, clarifying, considering alternatives, etc.
Attention needs to be called upon possible sources of conflicts deriving from current curricula/syllabi constraints and contextual circumstances.

10.1.2. Specific cases

About images and their use in science teaching

Images are more and more used in science teaching; their presence in textbooks and other teaching materials is much higher than in the recent past, the complexity and appeal of the used visual language is increasing. It is usually assumed that images convey information in transparent ways and that no difficulties are encountered in reading and interpreting them. This rather naive viewpoint should not be assumed. The following research-based recommendations should be taken into account when designing and implementing teacher education programs.

- Teachers should be trained to be extremely careful with visual language particularly in drawing and interpreting schemes, graphs, diagrams.

- Images should be presented as a coherent whole of different elements aiming at conveying a message
- The efficacy of using images should be increased by building a more explicit teachers' awareness of the used visual language and of its relation with disciplinary ideas, concepts, results, etc.
- Students and teachers should be provided specific training in the use of real-time graphs produced in experiments based on computer driven sensors. The optimisation of image's readability and the interpretation of the unique features of real-time graphs (including artefacts) should be particularly addressed
- For better textbooks and other teaching materials, authors and designers of images should collaborate with curriculum (didactic) experts to optimise the matching of images and concepts according the level of students' understanding

A number of sources of potential difficulty in reading images have been identified, suggesting the following advice to designers of didactical images:

- be careful when mixing symbolic and real entities;
- pay attention to highlighting of elements intended and accidental;
- encode different meanings of similar symbols in different ways;
- pay attention to the wording and placing of verbal elements;
- be careful with layout when several images are to be integrated;
- remember that compositional structures are used to read meaning into images;
- be cautious about narrative in images - it may distract even while engaging interest.

About the use of Informatic Tools (IT)

The educational use of IT is increasing very rapidly; their impact in science education can affect very important areas of the teaching-learning processes.
The following research-based recommendations should be taken into account for improving the design and implementation of teacher education programs.

- The training should take care of the fact that the use of IT in science is still 'fragile' and 'patchy', but that this situation is changing fast.
- Strong attention needs to be paid to a whole school / whole curriculum policy in the development of students' skills with general purpose IT, so that no individual teacher or school subject feels that they are shouldering an unnecessary burden.
- Attention should be paid in claiming that the use of IT always saves time. Often they do not in literal sense, since time and work is needed to use IT in a naturalised way and to take advantage of their potentialities (e.g. facilitation of students' interactions, analysis of different variables, rapid repetition of experiments, etc…). To make a convincing claim that IT help deepen understanding, this should not be a general claim, but given with specific examples of classroom activities and an analysis of the benefits that are felt to be associated with them.
- The training should aim at creating clusters of teachers in each school; diffuse expertise among fellow teachers favour greatly the take-up of innovations based on IT.
- The links amongst the various components of the proposed IT should be explicitly addressed and clarified to facilitate its understanding, as for instance in the case of real-time experiments systems.
- Special attention should be called upon the integration of the proposed IT in a coherent set of activities, based on other technologies, within a teaching sequence.
- Teachers' awareness about the appeal of IT should be increased: they may attract all students' attention.

11. Dissemination and/or exploitation of results

Many different plans have been followed to disseminate the results of the STTIS Project.

11.1. Public presentation of the project and first results

The STTIS partners chose the ESERA (European Science Education Research Association) conference held in Kiel (1999), since its impact in International basis of this conference, as the first public presentation of the STTIS Project and its first results on WP1, WP2, and WP3.

Two symposia were organized in **ESERA Conference 1999**

- Symposium : Science teacher training in an information society (STTIS) 1: Teachers' use of innovative sequences.
- Symposium: Science teacher training in an information society (STTIS) 2: The innovative use of symbolic representations and informatic tools.

Presentation at international level has also carried out in the **International Conference GIREP 2000** (Groupe international de Recherche sur l'Enseignement de la Physique) by means of two symposia:

- Symposium 1: Students' Difficulties when Reading Images (STTIS Project).
- Symposium 2: The implementation of innovative teaching sequences (STTIS Project)
- Two individual contributions. (More information can be found in the deliverable RW6, Work package 6)

Presentation in **ESERA Conference 2001**, in Thessaloniki, the last STTIS results through a symposium:

- Symposium: Designing research-based training materials to address some teaching innovations, and some individual contributions

Relevant dissemination activities at national level:

Dissemination of the French team

- 28 October 2000, Lile, IN the frame of the national meeting of the UNION DES PHYSICIENS. Some results of the STTIS French team were mentioned at the presentation *Acquis de la didactique et prise de décisions pour l'enseignement: quels rapports?* By L. Viennot

Dissemination from Italian team:

- Genova 11-14 febbraio 2001, E. Sassi Le difficoltà di apprendimento in fisica ed il laboratorio in Tempo-Reale, Convegno TED Tecnologie Didattiche Innovative, Atti a cura di D. Persico pg 80-83;
- Congresso Nazionale Società Italiana di Fisica, 1999. Testa I., Monroy G., Sassi E., Giberti G., Balzano E.Una strategia didattica per affrontare, nella Secondaria Superiore, dei nodi concettuali su "Moto e Forza": trasformazioni delle intenzioni didattiche della proposta operate dagli insegnanti. Bollettino pg 41;
- Congresso Nazionale Società Italiana di Fisica, 2000. E. Sassi, G. Monroy, I. Testa Progetto STTIS: alcuni criteri per realizzare interventi e materiali per la formazione insegnanti Bollettino pg 17;
- Congresso Nazionale Società Italiana di Fisica 2000. G. Monroy, G. Giberti, E. Sassi, I. Testa Immagini di grafici cinematici da esperimenti in tempo reale (Imm. Real-Time): elementi grafici/testuali che possono causare difficoltà di lettura/interpretazione, Bollettino pg 17

Dissemination of the Norwegian team

- **The National Report of the STTIS project, as carried through in Norway, is put on the National STTIS website: http://www.ils.uio.no/forskning/sttis/engelsk. (maintained by our institute), for free downloading and use by physics teachers and other interested agents. The report is in English. Information about this website has been disseminated to the Physics Teacher Association of Norway, and to other Norwegian universities and colleges.**

- **The two workshops for teacher training (Work Package 5) have also been put on this website (in both Norwegian and English versions), for free downloading and use.**

Dissemination of the Spanish team

- April, 1998. In the frame of a Conference on science education research presentation to secondary school teachers Presentation of STTIS project by R. Pintó and R. Gomez. Universitat Autònoma de Barcelona (Spain)..

Dissemination of the U.K. team

- At the ASE "International Conference on the 'Teaching of energy'" in January 2000, in Leeds, UK, presentation of the results of WP3 UK National Report. By F. Stylianidou.

- April 15-16, 2000 First European Conference On Modern Education: 'Applications of Innovations in Education', Organised by the Centre for Research and Development of Ziridis School Athens, Greece, Invited Plenary Talk F. Stylianidou presented the paper 'Teachers' transformations of innovations' in Greek, based on WP1.2.

- May 3-5, 2000 Second Panhellenic Conference on 'Science Education and Applications of New Technologies in Education', Nicosia, Cyprus, Paper presentation in Greek. F. Stylianidou presented the paper 'Innovations in the teaching of energy: their transformation in the classroom' based on WP3 UK National Report.

- March 25-28, 2001 NARST Annual Conference, St. Louis, USA, Paper presentation F. Stylianidou presented the paper 'Teachers' transformations of a national curriculum innovation about energy' based on WP3 UK National Report.

11.2. Publication of results in International Journals.

Publications in International Journals are envisaged as an important part of dissemination of results. The STTIS Consortium has planned a cascade of publications in prestigious research journals since a lot of relevant material has been produced. Until this moment:

- An special issue with the results of Work package 2 has been accepted for publication in the International Journal of Science Education.
- Other publications are in progress for Science Education and Instructional Science

11.3. Congress organization

The central task of dissemination has been the organisation of the GIREP International Conference Physics Teacher Training Beyond 2000, held in Barcelona (2000). The members of the STTIS project played a very active role in this congress, both as organisers and as expert participants. Dissemination of results of the STTIS project was extensively carried out in the Conference. The results are contained in the Proceedings of the Conference published by Elsevier Editions.

All the contributions of STTIS members referred above have been gathered in the deliverable RW6 (Dissemination activities: Presentation of STTIS results at the International Conference Physics Teacher Education beyond 2000)

11.4. Design and maintenance of a WEB site.

Due to the nature of the documents elaborated by the STTIS project the electronic format has been chosen for their dissemination. The WEB site http://www.blues.uab.es/~idmc42 containing all the STTIS material, has been mentioned in the previously mentioned dissemination tasks. It can be already said that it could be consulted by many people around the world.

11.5. Future planned disemination

September 2001 at the Congresso Nazionale Società Italiana di Fisica 2001 E. Sassi, G. Monroy, I. Testa Progetto STTIS (Science Teacher Training in Information Society): RTEI un workshop per facilitare l'adozione della proposta didattica "Esperimenti e Immagini in Tempo Reale "

September 2001 Symposium on STTIS results at the Congreso Internacional de Enseñanza de las Ciencias. R. Pinto, R. Gutierrez, E. Sassi, J. Ametller, D. Couso, O. Perez.

- Pintó, R. and Gutierrez, R.. *Tendencias detectadas ante la implantación de innovaciones en los cursos de Ciencias.*.
- Gutierrez, R. and Pintó, R. *Marcos interpretativos de las tendencias transformadoras detectadas en los profesores al enfr4entarse a materiales curriculares innovadores.*
- Sassi, E. *La formación de profesores. Los enfoques del trabajo experimental en tiempo real: el caso de la física.*
- Ametller, J., Pintó, R. and Gutierrez, R. *La utilización de imágenes en los cursos de ciencias: dificultades delos alumnos y estrategias para superarlas.*
- Couso, D., Pintó, R. and Gutierrez, R. *Materiales para la formación de profesores sobre degradación de la energía. Una propuesta de utilización de resultados de investigación.*
- Pérez, O. and Pintó R. *La integración de una herramienta informática para el trabajo experimental en un curso de ciencias: un estudio de casos.*

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Giorgio Olimpo IstitutoTecnologie Didattiche CNR Genova Italia
Sara Lombardi Universita Federico II da Napoli, Italy

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ANNEXES

FINAL REPORT

RESTRICTED

Contract nº: ERB-SOE2-CT97-2020
Project nº: PL 97/2125

Title: Science Teacher Training in an Information Society (STTIS)

Project coordinator: **Roser Pintó (Universitat Autònoma de Barcelona)**

Partners:

Laurence Viennot
Laboratoire de Didactique de la Physique dans l'Enseignement Supérieur.
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Reference period: December 1, 1997- December 1, 2000

Starting date: December 1, 1997

Duration: 36 months + 3

Date of issue of this report: April 30, 2001

Project financed within the TSER Programme

Annex 1. Publications and Conference presentations

Publications

1) An special Issue on visual language in science education with STTIS results has already been accepted for publication in the International Journal of Science Education. The special issue includes six papers:

- *The Science Teachers Training in an Information Society Project.* R. Pintó.
- *Reading images in optics: students' difficulties, and teachers' views.* P. Colin, F. Chauvet, L. Viennot.
- *Students' reading of innovative images of energy at secondary school level.* J. Ametller and R. Pintó.
- *Students' reading Images In Kinematics: The Case Of Real-Time Graphs.* I. Testa, G. Monroy, E. Sassi.
- *Analysis Of Science Textbook Pictures About 'Energy' And Pupils' Reading Of Them.* F. Stylianidou, F. Omerod and J. Ogborn.
- *Students' Difficulties in Reading Images: Comparing Results from Four National Research Groups.* R. Pintó and J. Ametller

2) *Proceedings of the Second International Conference of the European Science Education Research Association (E.S.E.R.A.). Research in Science Education. Past, Present, and Future. August 31 – September 4, 1999, Kiel, Germany.* M. Komorek, H. Behrendt, H. Dahncke, R. Duit, W. Gräber, A. Kross (eds.). It contains the contributions of the STTIS with 2 Symposia:

- Symposium: Science teacher training in an information society (STTIS) 1: Teachers' use of innovative sequences. R. Pintó (organizer), L. Viennot (discussant).

- *Teaching Motion and Force in Secondary School through real-time experiments: some transformations of the didactic strategies by teachers.* G. Monroy, E. Balzano, G, Giberti, E. Sassi.
- *Transformation of didactic intentions by teachers the case of geometrical optics in grade 8 in France.* C. Hirn and L. Viennot.
- *Teaching about Energy in Secondary Schools: The case of two innovations and teachers' transformations of them.* F. Stylianidou and J. Ogborn.

- Symposium: Science teacher training in an information society (STTIS) 2: The innovative use of symbolic representations and informatic tools. E. Sassi (organizer), J. Ogborn (discussant).

- *Images in optics and corresponding learners' difficulties: awareness and decision-making in teachers.* F. Chauvet, P. Collin, L. Viennot.
- *Students' reading of innovativeimages on energy in secondary school level.* J. Ametller, R. Gómez, R. Pintó.
- *Using spreadsheets in the science classroom: intentions, expectations and practice in teaching physics at secondary school level.* A. Quale and O. Andresen.

3) International Conference Physics Teacher Education Beyond 2000. Selected Contributions" R. Pints & S. Suriñach (eds). Elsevier Editions. ISBN. 2-84299-312-8 Paris. 2001
"Proceedings of the International Conference Physics Teacher Education Beyond 2000" R. Pints & S. Suriñach (eds). CD Production Calidos. ISBN: 84-699-4416-9 Barcelona. 2001.

Plenary Lectures of STTIS members

Choosing the science curriculum. Jon Ogborn.

Mental models and the fine structure of conceptual change. Rufina Gutierrez.

Anticipating teachers' reactions to innovations. Examples in optics. Laurence Viennot.

Lab-work in physics education and informatic tools: advantages and problems. Elena Sassi.

Contributions with results on WP1

IT tools in physics teaching - curriculum implpications. A. Quale.

Contributions with results on WP2

Symposium: Students difficulties when reading images

Students' difficulties on reading innovative images of energy. J. Ametller & R. Pintó.

Teachers' interpretation of students' difficulies when reading images: the case of real-time kinematics graphs. G. Monroy, I. Testa & E. Sassi.

Reading Physics textbook pictures about 'energy': pupils' difficulties and teachers' reactions. F. Stylianidou, F. Ormerod & J. Ogborn .

Poster with results on WP2

Teachers' use in class-work of images of real-time graphs. I. Testa, G. Monroy & E. Sassi.

Contributions with results on WP3

Symposium: The implementation of Innovative Teaching Sequences

Teaching about energy and training for innovation. R. Boohan, F. Stylianidou & J. Ogborn.

Teachers' interpretations of a proposal on "Motion and Force" in secondary school: tranbsformations of didactic intentions. G. Giberti, G. Monroy, I. Testa & E. Sassi.

Ontologies and Physics teachers training. R. Gutierrez & R. Pintó.

Transformation of didactic intentions by teachers: the case of a teaching sequence about colour (Grade≥8). F. Chauvet.

Round table with the presence of STTIS members.

R. Gutierrez (coordinator) J. Ogborn (discussant).

All the contributions of STTIS members referred above have been gathered in the deliverable RW6 (Dissemination activities: Presentation of STTIS results at the International Conference Physics Teacher Education beyond 2000)

Conference presentations

Year 1999.
Second International Conference of the European Science Education Research Association (E.S.E.R.A.). Research in Science Education. Past, Present, and Future. August 31 – September 4, 1999, Kiel, Germany.

- Symposium: Science teacher training in an information society (SSTIS) 1: Teachers' use of innovative sequences. R. Pintó (organizer), L. Viennot (discussant).

- *Teaching Motion and Force in Secondary School through real-time experiments: some transformations of the didactic strategies by teachers.* G. Monroy, E. Balzano, G, Giberti, E. Sassi.
- *Transformation of didactic intentions by teachers the case of geometrical optics in grade 8 in France.* C. Hirn and L. Viennot.
- *Teaching about Energy in Secondary Schools: The case of two innovations and teachers' transformations of them.* F. Stylianidou and J. Ogborn.

- Symposium: Science teacher training in an information society (STTIS) 2: The innovative use of symbolic representations and informatic tools. E. Sassi (organizer), J. Ogborn (discussant).

- *Images in optics and corresponding learners' difficulties: awareness and decision-making in teachers.* F. Chauvet, P. Collin, L. Viennot.
- *Students' reading of innovativeimages on energy in secondary school level.* J. Ametller, R. Gómez, R. Pintó.
- *Using soreadsheets in the science classroom: intentions, expectations and practice in teaching physics at secondary school level.* A. Quale and O. Andresen.

Year 2000
XVIII GIREP International Conference: Physics Teacher Education Beyond 2000, August 27 – September 1, 2000, Barcelona, Spain.

Plenary Lectures of STTIS members

Choosing the science curriculum. Jon Ogborn.

Mental models and the fine structure of conceptual change. Rufina Gutierrez.

Anticipating teachers' reactions to innovations. Examples in optics. Laurence Viennot.

Lab-work in physics education and informatic tools: advantages and problems. Elena Sassi.

Contributions with results on WP1

IT tools in physics teaching - curriculum implpications. A. Quale.

Contributions with results on WP2
Symposium: Students difficulties when reading images

Students' difficulties on reading innovative images of energy. J. Ametller & R. Pintó.

Teachers' interpretation of students' difficulies when reading images: the case of real-time kinematics graphs. G. Monroy, I. Testa & E. Sassi.

Reading Physics textbook pictures about 'energy': pupils' difficulties and teachers' reactions. F. Stylianidou, F. Ormerod & J. Ogborn .

Poster with results on WP2

Teachers' use in class-work of images of real-time graphs. I. Testa, G. Monroy & E. Sassi.

Contributions with results on WP3
Symposium: The implementation of Innovative Teaching Sequences

Teaching about energy and training for innovation. R. Boohan, F. Stylianidou & J. Ogborn.

Teachers' interpretations of a proposal on "Motion and Force" in secondary school: tranbsformations of didactic intentions. G. Giberti, G. Monroy, I. Testa & E. Sassi.

Ontologies and Physics teachers training. R. Gutierrez & R. Pintó.

Transformation of didactic intentions by teachers: the case of a teaching sequence about colour (Grade≥8). F. Chauvet.

Round table with the presence of STTIS members.

R. Gutierrez (coordinator) J. Ogborn (discussant).

All the contributions of STTIS members referred above have been gathered in the deliverable RW6 (Dissemination activities: Presentation of STTIS results at the International Conference Physics Teacher Education beyond 2000)

Year 2001

Third International Conference of the European Science Education Research Association (E.S.E.R.A.). Science Education Research in the Knowledge Based Society. August 21 – August 25, 2001, Thessaloniki, Greece. (Accepted presentations)

- Symposium: Designing research-based training materials to address some teaching innovations. Dr. Roser Pintó (organiser). Discussant: Fani Stylianidou

- *Computer modelling and simulation in science lessons: using research into teachers' transformations to inform training.* Fani Stylianidou, Richard Boohan, Jon Ogborn
- *Teaching about energy conservation and degradation. using research into teachers' transformations to design material for teacher training.* Roser Pintó, Rufina Gutierrez, Digna Couso
- *Designing research based strategies and tools for teacher training. Reading images in optics.* Philippe Colin, Françoise Chauvet, Gérard Rebmann and Laurence Viennot
- *Research-based Teacher Training about Real-Time Approaches: some guidelines and materials.* Elena Sassi, Gabriella Monroy, Italo Testa

- *Teachers' transformation of images representing the concept of system and environment.* Jaume Ametller, Roser Pintó

Other outputs

The main output (other that those listed) that is already available is the STTIS WEB site. It is hosted by the Universitat Autonòma de Barcelona group and its electronic address is: http://www.blues.uab.es/~idmc42/

This site contains the deliverables and some other information related to the STTIS project. It also has a private section for the partners.

Annex 2. List of deliverables

Code	Deliverable title	Status
RW0	Outline and Justification of Research Methodology: Work Packages WP1, WP2 and WP3	Completed
RW1	The state of the art in the use and value of informatic tools. The nature of use by science teachers of informatic tools	Completed (The Sub Work Package 1.3 was abandoned (as agreed with the scientific officer)
RW2	Investigation on the difficulties in teaching and learning graphic representations and on their use in science classrooms	Completed
RW3	Investigation on teacher transformations when implementing teaching strategies	Completed
RW4	Teachers Implementing Innovations: Transformation Trends	Completed
MW5	Teacher training materials favouring the take-up of innovations	Completed
GW5	Teacher trainer's Guide for the use of teacher training materials favouring the take-up of innovations	Completed
RW6	Dissemination activities: Presentation of STTIS results at the International Conference Physics Teacher Education beyond 2000	Completed
RW7	Guidelines for policy-makers of teacher training programs	Completed

Annex 3. STTIS Reports

STTIS Project, 1998, Internal Report RW0: Outline and Justification of Research Methodology: Work Packages WP1, WP2 and WP3.

Balzano, E., Giberti, G., Monroy, G., and Sassi, E., 1999, Transformations done by teachers when using an IT: the case of MBL (micro computer based laboratory). NR1.2-IT.

Contini, M., Ott., M., and Sassi, E., 1999, The State of the Art in the Use/Value of InformaticTools. NR1.1 -IT

Chauvet, F., Colin, P., and Viennot, L, 1999, Reading images in optics. Students difficulties, teachersí views and practice. NR2-FR.

Chauvet, F., Hirn, C., and Viennot, L., 1999, Investigation on teacher transformations when implementing teaching strategies. FR NR3.

Monroy, G., Testa, I., Giberti, G., and Sassi, E., 1999, Transformation of didactic intentions: The Italian case of ìmotion and forceî proposal. NR3-IT.

Pinto, R., and Ametller, J., 2000, Using images to teach Energy: students' difficulties, teachers' interpretations and teachers' transformations. NR2-SP.

Pinto, R., Ametller, J., & F. Chauvet, P. Colin, G. Giberti, G. Monroy, J. Ogborn, F. Ormerod, E. Sassi, F. Stylianidou, I. Testa, L. Viennot (2000). Investigation on the difficulties in teaching and learning graphic representations and on their use in science classrooms. RW2. STTIS Project.

Pinto, R., Gutierrez, R. and Ametller, J. Andresen, O, Balzano, E. Boohan, R., Chauvet, F., Colin, P., Couso, D., Giberti, G., Hirn, C., Kolsto, S.D., Monroy, G., Ogborn, J., Quale, A., Rebmann, G., Sassi, E., Stylianidou, F., Testa, I., Viennot, L., 2001, Teachers Implementing Inovations: Transformations Trends, RW4.

Pinto, R., Ametller, J., Boohan, R., Chauvet, F., Giberti, G., Gutierrez, R., Monroy, G., Ogborn, J., Ormerod, F., Quale, A., Sassi, E., Stylianidou, F., Testa, I., Viennot, L., 2000. Dissemination activities. Preseantation of the STTIS results at the Internatinal Conference Physics Teacher Education Beyond 2000. RW6.

Pinto, R., Perez, O., and Gutierrez, R., 1999, The State of Art in the Use and Value of Infomatic Tools. The Spanish case. NR1.1-SP

Pinto, R., Perez, O., and Gutierrez, R., 1999, Implementing MBL (Microcomputer Based Laboratory) technology for the laboratory work in Compulsory Secondary school Science classes. NR1.2-SP.

Pinto, R., and Gomez, R., 1999, Teaching about energy in Spanish secondary schools: teachersí transformations of innovations. NR3-SP.

Quale, A., Andresen, O., and Kolst¯, S.D., 1999, The State of Art in the Use and Value of Informatic Tools. The Norwegian case. NR1.1-NO

Quale, A., Andresen, O., and Kolst¯, S.D., 1999, Using IT-tools in the teaching of physics in Norwegian secondary schools: intentions, expectations and practice. NR1.2-NO.

Rebmann, G.,1999, The State of Art in the Use and Value of Informatic Tools. The French case. NR1.1-FR

Rebmann, G.,1999, Investigation of actual use of informatic tools by science teachers: the French case. NR1.2-FR.

Sassi, E., Monroy, G., Testa, I., and Giberti, G., 2000, Reading and interpreting graphs from real-time experiments: studentsí difficulties, teachersí interpretations and class practice. NR2-IT.

Sassi, E., Monroy, G., Testa, I., Ametller, J., Andresen. O., Balzano, E., Boohan., R., Chauvet, F., Colin, P., Couso, D., Giberti, G., Gutierrez., R., Hirn-Chaine, C., Ogborn, J., Pintó, R., Quale, A., Rebmann, G., Stylianidou, F., Viennot, L., 2000. Teacher training materials favouring the take-up of innovations. RW5

Sassi, E., Ogborn, J., Pintó, R., Quale, A., Viennot, L., 2000. Guidelines for policy-makers of teacher training programs. RW7

Stylianidou, F., Ogborn, J. and Contini, M., Gutierrez, R., Kolst¯, S. D., Ott., M., Perez, O., Pinto, R., Quale, A., Rebmann, G., Sassi, E., Viennot, L., 1999,The State of Art in the Use and Value of Informatic Tools. RW1.1

Stylianidou, F., and Ogborn, J., 1999, The State of Art in the Use and Value of Informatic Tools. The UK case. NR1.1-UK

Stylianidou, F., and Ogborn, J., 1999, Teachers using computer modelling and simulation in the science classroom: the English case. NR1.2-UK.

Stylianidou, F., and Ogborn, J., 1999, Teachers' transformations of innovations: the case of teaching Energy in English secondary schools. NR3-UK.

Stylianidou, F., Ogborn, J. and Balzano, E., Giberti, G., GutiÈrrez, R., Kolst¯, S. D., Monroy, G., Perez, O., Pinto, R., Quale, A., Rebmann, G., Sassi, E., Viennot, L., 2000, The nature of use by science teachers of informatic tools. RW1.2.

Stylianidou, F., Ormerod F., & Ogborn, J. (2000). Difficulties in teaching and learning with pictorial representations. NR2-UK.

Viennot, L. and Balzano, E., Chauvet, F., Giberti, G., Gomez, R., Hirn, C., Monroy, G., Ogborn, J., Pinto, R., Sassi, E., Stylianidou, F., 1999, Investigation on teacher transformations when implementing teaching strategies. RW3