TRANSFORMATIVE RESEARCH ACTIVITIES
CULTURAL DIVERSITY AND EDUCATION IN SCIENCE

FINDINGS AND RECOMMENDATIONS FOR RESEARCH-BASED PRACTICE IN SCIENCE EDUCATION

TRACES is **T**ransformative **R**esearch **A**ctivities: **C**ultural diversity and **E**ducation in **S**cience

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INTRODUCTION

This report presents the conclusions of the research developed in the framework of the TRACES project during the last two years. The conclusions are presented in the form of recommendations for possible future initiatives and policies focused on science education. These recommendations are aimed to all the relevant actors in the science education scenario and mainly to academic researchers, policy makers and teachers in all grades from primary to high school.

The process that guided the TRACES consortium to the recommendations passed through an international survey of stakeholders' perceptions about science education, the design and implementation of field actions involving hundreds of teachers in the six partner countries, the elaboration of case studies analysing the experiences made during the field actions and a cross comparison of the conclusions of the national case studies that was enriched by a final workshop/conference involving representatives of all the actors involved in the project (mainly teachers and university researchers).

The report is organised as follows. In Section 1, structure and general aims of the project are summarized in order to better place the recommendations in the wider framework of the project. Section 1.1 describes the way the consortium worked as a whole in order to share a common reference frame for the project activities at all its stages. Section 1.2 summarise the approach used in carrying the national surveys at the beginning of the project. Section 1.3 summarise the approach and content of the case studies developed by each partner. Section 1.4 briefly summarizes the final steps bringing the consortium from the case studies to the elaboration of the recommendations. Section 2 begins with a general description of the findings emerging from the case studies and then presents the seven recommendations, each of them being organised in findings leading to the recommendation, statement of the recommendation and explanation of the statement.

1 THE RESEARCH PROCESS

Traces is a two-years research project funded within the EU 7th Framework Programme. The project started in July 2010 and involved six partner countries (Argentine, Brazil, Colombia, Israel, Italy and Spain). With a special focus on the cultural dimensions of learning, TRACES main aim was to investigate the factors determining the gap between science education research and actual teaching practice.

The project was structured in four main stages:

Stage 1: A survey of teachers' (and other stakeholders') perceptions about science teaching conducted in all the six partner countries;
Stage 2: Implementation in each partner country of field actions involving hundreds of teachers in the design, carrying out and analysis of educational activities in classrooms and in a process of critical reflection on their practice;
Stage 3: Production of several case studies in each partner countries, analysing the process of implementation of the field actions and the lesson learnt during their development;
Stage 4: Elaboration of the project final recommendations based on the surveys' results and on findings from case studies.

Although the project has continually been informed by all the well-known extensive international surveys on science education already available (TALIS, TIMMS, OECD-Pisa), we decided to start TRACES with a specifically designed survey for three main reasons:

- having a chance to investigate more specifically the stakeholders' perception about the reasons for the actual distance between schools and the other actors involved in science education;
- posing the basis for the subsequent steps of the project, starting to directly involve teachers (and other relevant actors) in the participative process of development of the TRACES activities;
- gaining a deeper understanding of the actual educational contexts in which the field actions had to be implemented.

After having accomplished the survey phase during the first six months of the project (the related analysis is reported in the TRACES deliverables D2.1-2.6), the TRACES consortium used hints coming from a compared analysis of the national surveys in order to design a general framework for the implementation of the national field actions (D3.1).

Then TRACES researchers spent over a year working side by side with teachers at the development of educational activities on the field and collected the findings emerging from these experience in the TRACES case study reports (deliverables D4.1-4.6). Although the main focus of the field actions was the investigation of the research-to-practice gap, the strongly participative nature of the activities resulted in a huge variety of directions undertaken in order to fulfil local needs and expectations. This is the reason why the present recommendations are not exclusively focused on the gap, but also on a number of related issues such as the exploitation of internal resources in

schools or the relationship of schools with the socio-cultural context in which they are based.

The consortium made a further compared analysis of the case study findings in order to come out with a draft of the TRACES final recommendations that was discussed with representatives of all the involved stakeholders during the project final conference (deliverables D5.1 and D6.1).

This report presents the final version of the recommendations which are the result of this long and complex cyclic process in which actions and reflection have been continually alternated at both the national and consortium levels. In parallel with the sharing of experiences within the consortium, the process towards the recommendations was also feed by the interaction with the TRACES external evaluators that contributed with their hints and visions at crucial steps in the development of the project.

The TRACES recommendations are aimed at all the stakeholders in the science education area: teachers, researchers, educators, school administrators, principals, policy makers. In fact, TRACES findings suggest the tension between research and practice have to be mitigated alongside with other tensions and gaps involving the relationships of schools with educational authorities, other educational institutions, local communities. The recommendations are aimed at sharing the lessons learnt during the two years of the project and at giving recommendations on actual initiatives to be undertaken in order to exploit already existing resources at their best and favour the establishment of communities involving different stakeholders in order to improve the way science is taught in schools.

1.1 Sharing experiences at the consortium level

The TRACES consortium brings together six research groups that are strongly varied in terms of previous experiences and specific expertise. All along the project lifespan the consortium exploited this variety of backgrounds guaranteeing enhanced confrontation among the partners through the coordination action carried out by the project Steering Committee and through enlarged workshops (involving researchers and sometimes other stakeholders in the local workgroups) carried out at crucial steps in the project development.

The TRACES Steering Committee (involving one member from each partner institution) took the responsibility for the project general management and acted as a scientific board guaranteeing the coherence with the project objectives of the implemented actions. The meetings of the Committee allowed the consortium to define common research frameworks for the project activities and refine them while happening taking into account hints and suggestions coming from each partner and the external evaluators.

The general framework for the national surveys was defined during the first steering committee meeting (organised at the very beginning of the project) and refined during

subsequent discussions using the consortium communication tools. Defining a common framework for the surveys represented a fundamental chance for the consortium to discuss in depth the general research framework of the project highlighting the specificities of each research group and partner country (see deliverable D1.2 and D3.1). The shared themes to be investigated through the surveys include:

- beliefs about founding ideas (theories) of science teaching and their connection to practice;
- aims and social role of science and/or science education;
- interaction with colleagues;
- perception of national initiatives and official indications on science education;
- perception of pre- and in-service training;
- barriers to effective practice;
- sources of materials/ideas for teaching;
- role of assessment procedures;
- sources vision of effective science teaching;
- role of external actors in school practice;
- gender related issues in teaching/learning.

This first confrontation put a strong basis for the development of the further stages of the project. Furthermore, the agreed general structure for the surveys resulting from this discussion revealed itself strict enough in order to have quantitative data from each partner country to be compared (teacher questionnaire common to all partner countries) and flexible enough in order to take into local specificities (interviews and focus groups with teachers and other stakeholders). The different stratification criteria used in each partner country allowed each research group to collect data that are significant according to the specific socio-cultural differences that are present in their territory (e.g. rural or native communities in South America, relevance of the private sector education in Catalonia). The wide degree of freedom in collecting qualitative data allowed each partner to define a strategy suitable to the local constraints (e.g. difficulties in reaching large-scale samples of teachers in Israel, relevance of School Administration Supervisors in Argentine) (see again deliverable D3.1 for further details).

A second fundamental moment of confrontation among the partners was the consortium workshop held at the end of the national surveys and aimed at a defining the common structure for the field actions (see Sections 1.3.1 and 1.3.2 and deliverable D3.1 for further details). An important outcome of this workshop was the agreement reached about the possible different nature of the field actions according to different local needs to the kind of interaction between the research groups and schools: field actions can cover single teachers, single schools or even a small number of schools. Nevertheless, the common key point is that in each field action the systemic aspects at the school level are investigated. It was agreed that the case studies in each country should share a number of key foci, including:

- interaction between teaching strategies and constraints/barriers to the implementation of those strategies;
- interaction with researchers;
- interaction with colleagues in the same school;

- interaction with wider communities of teachers;
- interaction with the wider local community.

Based on these insights emerging from this consortium workshop, the TRACES coordination team produced common indications for the upcoming field actions.

During the following months the consortium communication tools were used to monitor the development of the field actions through continuous exchange of documentation materials. The further steering committee meetings were mainly focussed on defining the common structure for the case studies reports according to the draft findings emerging from the national field actions. The wide degree of freedom agreed about the nature of the field actions gave rise to a reach variety of kind of interventions in schools including small or large groups of teachers, single schools or groups of schools, different dynamics of interaction (classroom activities entirely designed together with teachers or adaptation of proposal coming from science education research), strongly varied socio-cultural contexts. Subsequently the Steering Committee worked in order to define a common structure for the case studies: on the one hand, the structure had to be flexible enough in order to favour a narrative description of what happened more than a schematic reconstruction; on the other hand, a common set of analysis categories allowing comparisons among widely different contexts had to be provided. The process towards the definition of the final template for the case studies was therefore long and complex but the end the consortium succeeded in defining a suitable structure leaving room for both a qualitative interpretative description of the development of the field action and on a more focused analysis of six main research questions (meta-analysis questions) included:

- What role does teacher education play?
    - Official training
        - Pre-service
        - In-service
    - Colleagues / community
        - Within the school
        - In teachers' networks / groups

- What role do educational authorities play?
    - Role of educational policy makers (official curriculum, official decisions)
    - Role of supervisors / inspectors
    - Role of external assessment
    - Role of incentives / teacher career

- What role do the school structure play?
    - Role of school (teachers) culture / tradition
    - Role of school administrative staff (headmaster, internal supervisor, …)
    - Role of school (student) culture
    - Role of structural issues (time available, school duties,…)

- What role do educational resources played?
    - Access to ICT structures
    - Available laboratories

- Adequate classrooms

- What role does the social community play?
  - Role of parents
  - Role of civil structures / social-economic context
  - Role of economic activity / industrial context

- What role does research in science education play?
  - Role of researchers
  - Teachers´ access to research results
  - Teachers´ perception of research
  - Role of research findings

After the delivery of the national case study reports, the coordination team started the meta-analysis of the collected findings and prepared a preliminary draft of the TRACES recommendations that was refined within the consortium and then discussed during the TRACES final conference (see Section 1.1.2)

1.1.1 Role of the external evaluators

TRACES included an element of independent evaluation through the interaction with three external experts committed to assessing both the process of development and results of the project. The external evaluators gave the consortium fundamental formative feedback about the development of the project actions at crucial steps in the project timetable.

The first evaluation report was delivered in coincidence with the development of the common consortium framework for the implementation of the field actions. The main hints coming for this pre-evaluation of filed actions were the following:

- while it is good to look at the complexity of the school system as a whole it is also fundamental to concentrate on more specific research questions;
- field actions have to be used as an opportunity to gain deeper information about the elements emerging from the surveys;
- focusing on the comparison of the TRACES results and relevant international surveys and projects;
- putting stronger emphasis on the (autonomous) role of teachers in developing the field action classroom activities.

These hints were deeply useful in order to refine the foci of attention in the development of the field actions.

The second evaluation report was delivered immediately before the TRACES final conference and suggested useful topics to be further discussed during the conference in order to get further hints on the development of the final version of the recommendations. Among the long list of suggestion we mention here some of those we perceived as the most significant:

- What is the ‘research community’ to be developed for an authentic teacher professional development? The role of researchers is mainly the one of ‘mediator’ or ‘coach’ or other roles could be found?
- What could be done in the present situation, if political changes and extra-funding are not easy to reach?
- Taking learners diversities into account not only means to take into account the community internal diversity but also to educate the community, the families, not only to accept but to appreciate such diversities. How the research results on individual diversities could be shared with the local community?

1.1.2 TRACES Final Conference

In line with the strongly participative nature of all the project activities, the process of construction of the TRACES final recommendations went through the crucial step of discussing with all the stakeholders involved what are the main issues on which the recommendations have to be focussed on and what the experiences developed in all partner countries have to tell about these issues. To this aim, the TRACES conference brought together representatives of the researchers from the partner institutions, teachers and school principals involved in the field actions, policy makers and school administrators from the partner countries and eminent international experts and asked all of them to give their contribution to the development of the final version of the TRACES recommendations.

The conference was mainly organised around three discussion groups each one focussing on one specific topic. The draft version of the TRACES recommendations was in fact organised according to three main topics that were defined within the Steering Committee, aggregating the meta-analysis research questions. The chosen topics were the following:

- Teacher education
- Teaching and school/political context
- Teaching and community

For each of the topic two statements of provisional recommendations were presented to the participants together with a number of challenging questions meant to start-up the discussion.

The main hints for the present version of the TRACES recommendations coming from the workshops held during the final conference are discussed in detail in deliverable D5.1.

1.2 Exploiting external collaborations (national surveys)

While teachers have been the main target of the project all along its duration, school principals, school administrators, other researchers in science education and policy makers have been involved with different roles in different stages of TRACES. The

involvement of these actors allowed the consortium to gain richer insights for the development of the project actions and to establish collaborations that will surely be exploited beyond the lifetime of TRACES.

In all partner countries the development and carrying out of the initial national surveys followed a general framework shared at the consortium level, while suitable criteria for the stratification of the samples in order to take into account different socio-cultural backgrounds, balance between public and private schools, different urban development grades (big cities, small towns, rural areas) among other relevant factors (see deliverable D3.1 for further details). Of course different strategies were necessary in order to reach a significant sample in each country.

In Argentine, a collaboration was established with the local coordinators of the Scientific and Technological Activities for Youth, a national initiative fostering school projects in S&T activated in 1991 in order to define the sample of schools for the survey. In order to establish contacts with the schools in the sample an agreement was settled with the Directorate of Primary and Early Childhood Education, which provided official authorizations in order to carry out the survey. The interaction with the Directorate proved to be a strategic for the overall development of the project. The Board of Supervisors at the Directorate recognized in fact the foci of TRACES as addressing important issues of the local school system and offered full cooperation during the survey phase. The Board requested access to the results of the investigation as a source of information meant to inform curricular policy.

In Brazil, the dissemination strategy for the survey implied the involvement of the Regional Education Coordinators and the establishment of collaboration with local institutions offering teacher training programmes and different research networks. Invitations to participate in the survey were sent also to private teachers of the Marist Brothers civil institution, teachers involved in in-service training courses at UBEA, the members of the Network of Research in School (a public network focused on sharing and exchange of innovative practice in education). Interviews were carried out with researchers and policy makers.

In Colombia, the Ministry of Education was contacted and informed about the objectives and strategies of TRACES. The Ministry provided a database of teachers in each of the regions involved in the survey. Other teachers were contacted through graduate and undergraduate programmes of the Department of Physics and training events organized by members of local TRACES team. A large number of teacher questionnaires were distributed on paper during dissemination meetings organized by UPN in each sample region. UPN involved in these dissemination activities core managers and supervisors who preside over the academic and administrative coordination of the various institutions set up by regional Districts. Relationships were established with teachers trade unions and associations of teachers which play an important role as a link between the administration and the academy. The TRACES proposal was well received among the higher authorities of the Ministry of Education because it was assumed as an initiative that provides significant opportunities for teacher training and professional development.

In Israel, any educational research involving schools requires the approval of the Ministry of Education in order to be carried out. Israeli researchers had to prepare a

formal application describing the detailed description of the study and its tools. The letter was sent to the chief scientist of the Ministry who is responsible for allowing research activity in schools. The permission was received after a few months of consideration process. Due to these specificities of the local context, the research group at HUJI considered that it would be nearly impossible to reach a significant large sample for the quantitative survey in the time at disposal. They therefore opted for a large number of in-depth interviews as the core of their national survey. Nevertheless, an invitation to administer the questionnaire was disseminated through the websites of all the five National Science Teacher Centres. The centres include teacher centres of science and technology (middle school) as well as physics, chemistry, biology and earth science (high school). On the small scale, interviews were carried out with science education researchers, policy makers, teacher educators, school principals and science teachers.

In Italy a collaboration was started with the Service of Statistics of the Ministry of Education (which is the national reference institution fur studies such as those carried out by Eurostat and OECD). The Service provided a random list of 500 schools in order to obtain a reasonable and unbiased coverage of the stratification criteria. A further enlargement of the sample was reached through explicit invitation sent to individuals or associations (e.g. the National Association of Science Teachers, Association for Science Education, Association of Catholic Teachers). A special questionnaire was developed and administered to school principals. On the small scale, interviews with researchers in science education researchers and policy makers were carried out in order to enrich the diversity of points of view included in the survey.

In Spain, in order to build a consistent database of schools, UAB researchers established a collaboration with the Serveis Territorials, the local education services representing the Department of Education of the Generalitat de Catalunya. The nine Catalonian district services were contacted by phone and email in order to spread the survey via official channels. Eventually, only two of them accepted to send the questionnaire to the schools under their jurisdiction. Administrative support was also asked via the General Resource Centre for science teacher training, which is an educational service belonging to the Department of Education (the main authority in education in Catalonia). They accepted to distribute the questionnaire within their internal database both of primary and secondary schools. Apart from these official channels, the Spanish team also exploited the database of schools provided by their institute of reference, the Research Centre for Science and Mathematics Education (CRECIM) of the Faculty of Education. Also, other science teachers' associations and groups of teachers usually collaborating with the CRECIM were asked to disseminate the questionnaire. On the small scale, the Spanish team involved teachers, school administrators, researchers in science education and policy makers and both personal interviews and focus groups.

The establishment of significant collaborations with different actors and network of actors during the field actions phase is described in Section 1.3.

Findings from all national surveys were presented in a symposium during the ESERA 2011 conference and published in the related proceedings (Balzano, 2012; Chaile, 2012; Marques Da Silva, 2012; Rodriguez-Simarro, 2012)

1.3 Case studies

1.3.1 Research framework

The issue of the relationship between research and practice in science education is complex. If on one side research is considered as crucial for improving science education (e.g. Duit, 2006; Osborne, Dillon 2010 and references therein), on the other side we also know that evidence about the impact of research on actual teachers' practice is still scarce. In a recent study, Ratcliffe et al. (2005) found that evidence-based change in teaching practice implies resonating with teachers' professional experience and beliefs about science education.

Some scholars have even questioned if teaching can be considered a research-based profession at all. Hargreaves, for example, argued (1996) that there are few areas in which research has provided a corpus of "research evidence regarded as scientifically sound and as worthwhile resource to guide professional action".

Another major problematic aspect is that often there is scarce consensus within the community of scholars itself about crucial issues such as the nature of science (Alters, 1997; Laudan, 1990; Taylor, 1996; Collins et al., 2001). More generally, there is little evidence on the effectiveness of any particular approach to teacher preparation (NRC, 2010). This is due, amongst other things, to the fact that "it is difficult to measure teacher effectiveness in valid and reliable ways", that establishing clear causal links between aspects of teacher preparation and outcomes for students is extremely difficult" (*Ib*.).

Furthermore, as professionals, educational practitioners have responsibility, autonomy and access to specialized bodies of knowledge (Furlong, 2000). Different types of knowledge, each based on distinctive forms of evidence gathered from different sources, influence the actions of teachers and other educational practitioners (Brown & McIntyre, 1993; Loughran, 1999). Teachers' knowledge is often tacit and the supporting evidence 'invisible' (Barthes, 1972). Tacit professional knowledge may be used intuitively and is thus difficult for individual practitioners to articulate explicitly (Eraut, 2000).

Bridging the research-practice gap in science education and sustaining the ongoing improvement in teaching and learning requires therefore more extensive investigation into all such aspects of the teaching reality. Recommendations and research agendas about a number of open questions for what regards improving evidence-based science teaching have been proposed in the literature (NRC 2007; Osborne, 2008; NRC, 2010). These include, e.g.: What is the relationship between different systemic factors in science education? How is practice influenced by policies, research and societal factors? How much are policies informed by research? What is important for teachers to know about their subject, pedagogy and their students? What is the role of teachers' beliefs and of their conceptions of science and science education? What is the role of the context? What are the conditions that sustain or hamper effective teaching? How does research-informed teaching improve students' performance?

TRACES Field Actions investigated some of these questions while observing the interaction between researcher and practitioners working together as peers.

1.3.2 Implementation

Field actions were developed in a large number of schools in all partner countries. The choice of the schools to be involved tried to follow the same stratification criteria used during the national survey and exploited the contacts established during the surveys itself.

The general vision of the field actions shared at the consortium level implied a collaborative research approach involving both teachers and university researchers in stable project workgroups designing and refocusing the actions during devoted periodic meetings. Each of the components was expected to give their contribution according to the following general framework:

University component
- Starting from a shared reflection on the ordinary work of teachers, stimulate the construction and contribute to the elaboration of the reference frame of the project workgroup (mediating open discussions; introducing hints for reflection; sharing references from literature)
- Contribute to the design and implementation of classroom activities
- Coordinate the documentation and analysis of the entire process of development the project activities (analysing materials produced in the classrooms; analysing audio and video recordings of activities; producing reports to be shared within the workgroup; stimulating shared reflection about decisions made, difficulties encountered, possible improvements)
- Stimulate the sharing of experience towards wider communities (other workgroups in the same country and at the consortium level, local networks of schools, local authorities, academic community)

School component
- Allowing the construction of the project workgroup in each core school (involving a significant number of teachers actively participating in the workgroup activities)
- Contribute to the elaboration of a reference framework for the specific workgroup
- Contribute to the design and implementation of the classroom activities (with particular reference to their transfer into ordinary school practice)
- Contribute to the analysis of the entire process of development the project activities (participating in observations and discussions; producing reports)
- Share experiences towards wider communities (other teachers in the same school, other workgroups developing similar activities, other stakeholders involved in the project networking activities)

This implementation framework has been used as a reference frame that has been declined and adapted in each partner country according to local processes and needs.

1.3.3 Short descriptions of the Case Studies in each partner country

1.3.3a Argentine

Case study 1

A survey-type diagnosis was sent to a sample of primary level schools and interpretative analytical study of the responses was carried out. Salta´s educational authorities were involved, soliciting permission for investigative action. Six Workshops were held with the participation of Supervisors, Directors and Grade Teachers. San José School, with a modality of EIB (Bilingual Intercultural Education), is selected as a case study. Teachers chose subjects from the annual curriculum for the FA, which had not been studied for lack of training, bibliography and didactic resources. The class proposal is set up with an advisory intervention of the TRACES team and the participating teachers (Science, bilingual and art teachers). The content of the intervention included: force at a distance, magnetic phenomena and electrostatics, magnetic force, magnet poles, attraction and repulsion, magnetic fields. Materials to used in class were provided by the researcher team. Students' products were exhibited to socialize learning processes between the institution and the Community.

Case study 2

Survey-type diagnosis sent to a sample of primary level schools, and interpretative analytical study of the responses; Contact with Salta´s educational authorities soliciting permission for investigative action; 6 Workshops were held with the participation of Supervisors, Directors and Grade Teachers; 3 Schools of a suburban context were chosen for the Field Actions; The class proposal is set up with TRACES advisory intervention and the participating teachers; Consideration, analysis and discussion of basic concepts: a) 5º Grade: reflection, refraction, light propagation in Geometric Optics, b) Second Grade: rectilinear light ray model, extended and punctual sources, formation of illuminated, penumbral and shadow areas, c) 7º Grade: substance, density, materials, properties; Collaborative advice to each classroom teacher in each of the schools selected in Salta City. This consisted in attention at two levels: content and pedagogy.

Case study 3

Survey-type diagnosis sent to a sample of primary level schools, and interpretative analytical study of the responses; Contact with Salta´s educational authorities soliciting permission for investigative action; 6 Workshops were held with the participation of Supervisors, Directors and Grade Teachers; The CS3 group shares a collaborative educational experience of training in the field of Renewable Energies in the Primary Educational Level of Salta; Invitation to participate in a Case Study; Teachers´ needs: a) training on basic issues of energy transfer lead plausible simple equipment to the classroom, b) support for conducting science fair type jobs, c) support materials and / or specific literature on the area of physics; Agreed training objectives, schedule, location, schedule and credits; Development of a video about how the solar water heater in support of school activities on the occasion of La Silleta Science Exhibition.

1.3.3b Brazil

Case Study 1

This case study involved 9 schools, 8 science teachers, 240 students in lower secondary school grades in Guaíba, a small city near Porto Alegre. The case studies wanted to answer the following main research question: How can the participation in a dialogical

and collaborative teachers-researchers group improve school practice in Education Through Research approach?
The field actions included the following activities: meetings of mixed workgroups (researchers and teachers), discussions about teaching approaches, planning of classroom activities, interaction with the Science Museum, observation of classroom activities and a final meeting at Guaíba with parents, students, teachers, researchers and policy makers.
The conclusions of the case study can be summarized as follows:
- teachers have understood that there are a variety of opportunities to make student actively participate in their learning process;
- more time is necessary to carry out the proposed activities;
- educational programs must define a new meaning for the educational process;
- family can also contribute to the improvement of science education;
- the Education Through Research (ETR) methodological approach proposed by the university researchers implied that students were responsible for their own learning.

Case Study 2
This case study was developed in a public elementary and lower secondary school based in the city of Lajeado. This school has developed an innovative teaching method centred on cycle-based (3 years) evaluation and interdisciplinary approach. 26 teachers and 320 students were involved in the activities together with the principal and some coordinators. The case study wanted to answer the following main research questions: What are the barriers and facilities to develop and implement this innovative teaching process? What is the role of research/academic knowledge in this process?
The field actions included the following activities: meetings with teachers, observation of classroom activities, support to teachers' design of innovative classroom activities, guided visit to the science museum.
The conclusions of the case study can be summarized as follows:
- educational programs should articulate knowledge among different areas in teaching practices;
- in order to build educational proposals based on school needs it is necessary to organize teachers' education teams composed by pre- and in-service science teachers, researchers and families;
- educational proposals must respect issue concerning the natural environment and the social context;
- science education research results are not always useful at school and need to be enriched in a process of action-reflection.

Case Study 3
This case study was developed within the institutional scholarships national program for pre-service teaching (PIBID). 4 physics teachers from different high schools were involved, each one supervising 5 pre-service teachers. The case study wanted to answer the following main research question: How does the interaction among in-service teachers, pre-service teachers and researchers affect the gap between research and practice?
The field actions included the following activities: meetings with teachers, observation of classroom activities, support to teachers' design of inquiry-based classroom experiments, discussions on the Education Through Research approach proposed by the university researchers, assessment of the classroom activities.
The conclusions of the case study can be summarized as follows:

- training programs like PIBID should consider the actual constraints of the school contexts;
- university and school should be places were devoted to host frequent discussions aimed at promoting reflection on the teaching practice;
- interactions between university and school should lead pre-service teachers to develop and test hypotheses;
- students and teachers' motivation is a key factor in changing teaching methodologies and adopting new approaches;
- the academic emphasis of teacher's training strengthens the traditional education.

1.3.3c Colombia

The development of the Colombian field actions took into account the same stratification criteria used for the national survey. This is the reason why UPN selected three different regions for the implementation of the field actions: Caribbean, Orinoco and District capital. Urban suburban and rural areas were defined; public educational institutions were selected; institutional team were formed with the participation of researchers and primary and middle school science teachers from eight public educational institutions in the three regions of the country. The construction of a collective sense for the development of field actions in each institutional team, helped to determine issues and problems related to science education in the basic and conceptual and methodological design routes that defined what we call Classroom Proposals. For the design of the classroom proposals the indications agreed within the Steering Committee were considered. Based on these criteria seventeen (17) classroom proposals were designed. The information that was collected allowed to reveal situations, relationships and interests about each institutional team, that warranted to be objectified, that is deepened in their singularity, through the case study anlysis.

Case Study 1

This case study was focused on the initial training of teachers in socially vulnerable school contexts. This case study was developed in the Escuela Comunitaria Fe y Esperanza de Altos of Casuca, in the city of Bogotá, were children in conditions of social vulnerability attend. The study puts science teachers in initial training of the Universidad Pedagógica Nacional, in a context of social vulnerability that allows them to challenge their pedagogical knowledge and discipline, produce pedagogical knowledge and to lead educational processes, through the design, development and systematization of classroom proposals to meet the communication, relational and cognitive needs of the children attending the school.

Case Study 2

This case study was focused on the relationship between educational environmental policy and the construction of classroom proposals for science teaching. This case study was developed in the Institución Educativa Campestre Monteverde, located in the eastern hills of Bogotá. This study recognizes and describes some science teaching practices conducted by teachers who appropriate the environmental perspective and adopt legal, faculty and student interests, the institutional conditions, requirements and needs of the educational system of the school community.

Case Study 3
This case study was focused on the relationship between research practices and science teaching practices. This case study was developed at the Instituto Pedagógico Nacional, located in Bogotá, school annex to the Universidad Pedagógica Nacional. The study seeks to understand the views and perspectives from which a group of science teachers, link their research practices to their practices of science education.

Case Study 4
This case study was focused on the transformation of science teaching practices of through the creation of links between school and community. The diversity and complexity in which the links between school and community are understood allowed this study to be a multiple case study with three regional scenarios (Bogotá, Santa Marta y Tauramena) and five institutions. In this case study the school-community link is treated as a relationship that allows us to understand the role that school communities have assigned to the teaching of science and to show how the appropriate school, reads and contributes to the understanding of social realities surrounding the school.

1.3.3d Israel

Case Study 1
The first case study within HUJI field actions investigated the application of a new mode of teaching the concept of weight in physics to the students of middle school of urban type. The product of academic research combined two basic innovations: the new concept definition (operational definition of weight) and pedagogy that included (1) Thinking Journey (TJ) format of dialogic mediated teaching, (2) historical setting of the subject matter and (3) triggering class observation. A Follow-up study documented the influence of this new teaching method on both students and teachers, their understanding of the weight concept and application of the method. Expert teachers led the experimentation in three classes and trained two practicing teachers. The findings pointed to the need for teachers' preparation to the new subject matter knowledge, discursive teaching, adjusting materials to the teachers' background and particular educational setting. The area of validity of TJ method was found. Teachers view the academy as the body that investigates education, produces new contents of teaching and pedagogy, negotiates the required changes with the Ministry of Education, supervises, supports, and supervises the implementation and teacher training.

Case Study 2
The second case study within HUJI field actions examined the factors that influence assimilation of a new research-based teaching method (Thinking Journey) applied to teaching the topic of life characteristics on various levels in a suburban middle-school (students, colleagues, school). The focus of the case study was on mediation of discussions in science lessons. The characteristics of effective discussions in the teacher-researcher's lessons were defined, and compared to the discussions in classes of two other teachers. Findings show that discussions in the other teachers' classes differed significantly compared to the teacher-researcher's class. We found that observing a lesson of an expert teacher, and then reflecting on their own teaching may be an effective way to influence teachers, and may help in bridging the gap between research and practice. The process of experimental teaching can be further discussed in a wider group of teachers and paralleled with a dialogue with the school principal.

Case study 3

The third case study within HUJI field actions investigated the application of a new pedagogy of Thinking Journey (TJ) (Schur, 1999; Schur & Galili, 2009) developed in university research to a special curriculum of astronomy for teaching day-night cycle through dialogic mediated interaction. The goal population of the teaching was the students who dropped out of regular schools for various social circumstances. We examined the impact of the method towards the teachers involved in the national educational project and students. An expert teacher, trained in TJ and experienced in working with the dropout students, led the experiment. A group of teachers originally lacking scientific background participated in a specially designed series of workshops. The experiment revealed the features of the required adjustment of the curriculum to the specific type of teachers and students, showing the crucial role of specific training in such extreme educational setting. The workshop received close cooperation with the administrators of the Ministry of Education, participated in the workshop.

1.3.3e Italy

Case Study 1

This Field Action was conducted in the Istituto Comprensivo "Via Ricasoli 30" in the city of Turin, Piemonte. The school is a newly formed comprehensive institute in which a kindergarten, two primary schools and one lower secondary school have been unified. This field action considered the problem of how the interaction between researchers and teachers might develop in addressing the institute curriculum issue. This is an interesting example of how education research may be perceived as disconnected from teaching practice if researchers-teachers interaction fails in developing on a participatory base. In fact, in the actual development of the common work all subjects selected originated from researchers' proposals. Although these proposals were always explicitly presented as open to debate, they were actually all accepted without debate and the agreement on this proposal was to a large extent passive by the side of the teachers. Therefore many of the teachers in the workgroup couldn't actually see the link between the topics selected as discussion foci and the overall subject of the project activities. For some of them, most of these subjects weren't even perceived as relevant to their teaching practice.

Case Study 2

This Filed Action was conducted in a primary schools in the city of Bra, a small town in the northern Italian region of Piemonte. The school presents a rather high percentage (ca. 50%) of students with migration background. Many of the teachers involved in the work group are very active in both professional development and research and development programmes covering the experimentation of innovative science education approaches. They are used to work with researchers and to document, analyse and discuss their practice with others. The main issues of this case study was how to make the most of the previous experience and to make it 'usable' so that teachers in the school do not need to reinvent the wheel over and over on questions on which precious work has already been done. Also, another emerging issue was that of reorganizing experiences from different professional development activities which are often perceived as isolated and difficult to be put together in an overall discourse on teaching. For the involved teachers, interaction with the researchers represented an opportunity to discuss and reflect on specific issues that are difficult to address otherwise in the usual practice. With respect to teachers' perception of research

findings and their link to practice, this case study suggests that what teachers referred to as 'human mediation' plays an essential role in bridging the gap.

Case Study 3

This Field action was conducted in an institute that gathers together five primary schools and one lower secondary school all based in the area surrounding Treviso in the north-eastern Italian region of Veneto. Some of teachers involved in the workgroup come from a long term experience of interaction among them that was built during the set-up of a local network participating in a project devoted to innovation in science education. Throughout this experience and others, these teachers had the opportunity to strongly interact with science education researchers. The central problem of this case study lies in the investigation of the possible contributions that the use of crosscutting concepts as unifying elements among topics can give in order to guide the development of a vertical science curriculum. The main lesson learnt within this case study concerns the missing elements in the general structural framework that regulates the interaction of external actors with schools. In order to make the interaction work, this framework has to be transformed towards the construction of agreements among researchers, teachers, school principals and school administrators that make it possible to remove a number of barriers, which also hinder the use of contributions to teachers' practice coming from science education research.

Case Study 4

The school is based in a middle-class neighbourhood in Naples. The workgroup is made of teachers who have voluntarily chosen to participate to the Field Action. Most of the people involved in the workgroup are expert science teachers. The central problem of this case study lies in the investigation of effective ways to develop a science curriculum topic vertically along the five grades of primary school. Initially, researchers provided teachers with researcher-based educational materials, with the aim of supporting the design of educational paths, but the initial experimentation in the classrooms of the planned actions was essentially based on ready-to-use scripts for classroom activities contained in those materials. By their side, teachers intended those a script as tools to deal with a curricular topic in an unusual and innovative way and immediately switched their attention from the construction of the educational path as we agreed it to the assessment of the efficacy of these tools in making their pupils learn the contents. From this case study emerged that moments of reflection on what happens in their classes have to be complemented with a non-occasional presence of the researchers in the classrooms, because this is the only feasible way to settle the missing link between academic literature and teaching practice.

Case Study 5

The intervention has been centred on a high school in Naples offering several kinds of course of studies: in scientific, linguistic and socio-psychopedagogical area. The unit of intervention has been enlarged form the only school, comprising a local network embracing two primary schools and a subject devoted to informal education. The work was carried out with two high school classes and concerned two issues: what works in classroom and what is the role played by the out-of-school context. The students of this school attend a course of study in socio-psycho-pedagogical area, so that their main part could be engaged in pedagogical jobs (mainly as teachers). The main question of this case study concerns the reconstruction of the ideas and opinions the students have about the way mathematics education is done at school. The contents of the debate and

the developed argumentation seems give us a picture characterized by a kind of naïve view of the role that mathematics literacy should play in the social community. Otherwise, the way to conduct the reflection, the capacity of analysis and the theme autonomously raised by the involved students (theme that in many case are coherent or fitting with research and policy interest) point out us that, perhaps, the ingenuousness of some position ensues by a lack of involvement of students in debates on this kind of issues.

Case Study 6

Liceo "A. Gatto" is a high school based in Agropoli, a small town in Cilento, south of Campania. The school collects student from the whole district of Cilento including towns of different size based on both the seaside and the internal (typically rural) areas. The central problem of this case study lies in the investigation of effective ways to promote the introduction of Inquiry-based science education activities within the practice of science teachers that have not been extensively exposed to the interaction with science education researchers. The main issue connected to the central problem of this case study stands in teachers' perception of science education research as something far from their actual practice. This perception is the strongest barrier towards the introduction of innovative proposals in schools. Nevertheless, this case studies gave hints about possible ways to tackle this deep gap between research and practice and produce actual change in teachers' practice: interaction between the academy and schools cannot be occasional; the construction of stable long-time relationships between the academy and schools have to be sustained by the education authorities; research-based approaches cannot be imposed with a top-down attitude; educational paths implemented by researchers in schools should be based on teachers' usual practice; teachers should be involved in a process of reflection about their work.

Case Study 7

This Field Action was conducted in a comprehensive institute based in Palermo, in a neighbourhood characterized by a very complex urban stratification and by the presence of pockets of poverty and social marginalization. The school is traditionally characterized by a strong social engagement in the territory. The central problem of this Case Study lies in the investigation of the ways the interaction between a group of teachers that are members of a school department and external actors such as science education researchers can work and how this relationship can sustain or hamper science teaching in the considered school. The teachers of IC "A. Ugo" seem to perceive themselves mainly as social and cultural promoter of the local community, which the school take part in. The centrality of this mission permeates all the school activities and can be considered the main key to the reading for the interpretation of the way several school activities are structured and carried out. This peculiarity also concerns issues regarding science and mathematics educations, in several aspects. In conducting their teaching activity, the teachers of this school recognize a great relevance to the knowledge background of the pupils, as well as to the skills they have built outside of the school, in everyday experiences, and that they bring to school, as a patrimony to be empowered and organized.

Case Study 8

This Field Action was conducted in a comprehensive institute based in Palermo, in a neighbourhood characterized by the presence of pockets of poverty and social marginalization. The central problem that has characterized this field action has

concerned the opportunity and the possibility to elaborate a unified vision about the way to guarantee a significant long-term experience in mathematics and science education to pupils attending the lower school levels. The whole experience could be considered at the light of possible couples of dichotomous elements. The opposition between necessity of continuity in educational experience and structural elements of fragmentation of work are picked out, as well as contradiction between recognizing of the opportunity to give place to divergent ways to think and act, versus the necessity to work, at school, to build competences and knowledge that are culturally well established. At the same time, this difficulty is intertwined with the opposition between 'what has to done' and 'what one is able to do', so that teacher feel themselves in a condition of inadequateness, for what concerns the field of science and mathematics education. Mainly this inadequateness is tracked back to their preparation. Anyway, the function of mediation among teachers about the relevant themes concerning their work was able to fire a development of the school and an exploitation of the interesting resources in school themselves.

1.3.3f Spain

Case Study 1

The first Spanish case study offers a comparison between two continuous professional development (CPD) initiatives (ICE and CDEC teachers' groups) characterized by their potential in front of what is usually done with regard to teachers training programs, mostly proposed by the Administration when talking about public and semi-private schools. Both initiatives, did already exist when TRACES project was started and present some characteristics that make them interesting to be analysed when looking for new ways to improve teachers' practice regarding science education. The First group (ICE) is group of teachers that meets monthly to exchange their experiences and to talk about new science education approaches. The second (CDEC) is a group of teachers who attended a training programme to become teacher trainers and continued to work as a group after the training programme ended.

In contrast to what is usual in the teachers training programs that primary school teachers receive, ICE's and CDEC's groups are long-term initiatives, with about ten years of existence. Teachers participate in each initiative in a voluntary way and are opened to share with their colleagues their experiences in order to improve their own practice. Another similarity between both groups is the fact that they are constantly in contact with science education research, being each group coordinated by a science education researcher and usually receiving advice, based on teachers' request, from external well-known science education researchers. Finally, both initiatives are related to the Regional Government of Catalonia, which has offered, in the case of the CDEC group, the opportunity of having some privileges that otherwise would not have been possible – like a time reduction in teachers' schedule in order to devote some time to the group activity. Bearing all these particularities in mind, the authors considered that analyzing these atypical initiatives would be interesting in order to identify some key features that would be profitable for future CPD initiatives.

Case Studies 2 and 3

The second type of case studies were based on activities carried out in semi-private Schools (Mare de Déu del Roser-Amilcar- and Mare de Déu del Lourdes-MDL- schools).

The decision of working with this kind of school is due to the fact that even though they are quite similar to public schools in terms of teachers' and students' profile, semi-private Schools' titularity implies a facility to arrange a specific whole school intervention. In this kind of school, the School Administration has the competence of deciding actions that involve the whole School faculty, such as choosing CPD initiatives for all teachers, while in public Schools these decisions are generally taken at an independent teacher level. MDL and Amilcar case studies arise from this need of finding new ways and methods to overcome teachers' limitations in both subject matter and didactical/pedagogical knowledge through useful professional development programs that can help teachers to work from the competence-based framework.

In the case of MDL School, a training programme regarding mathematics competences was implemented with a group of 12 primary School teachers at the Mare de Déu de Lourdes School in the town of Mataró, Barcelona. In this School, the initiative for this programme came not only from the school's management board, which proposed an initial training activity for teachers, but also from teaching staff themselves. The training model implemented had three elements: broad training as a group, model classes and group reflection by teachers from each primary stage regarding the practice they have observed. The topic addressed in the model classes was based on the implementation of a project designed to bring innovation to the mathematics classroom, the focus in this case being on number development and mental calculation strategies.

In the case of Amilcar School, a teacher education initiative regarding science competences was implemented with a group of 25 kindergarten and primary School teachers at the Mare de Déu del Roser – Amilcar School in the city of Barcelona. In this case, the initiative for this programme came only from the school's management board, which asked for an initial training activity for teachers. The teachers' educator team offered a training intervention programme regarding science competences, more specifically a programme that included the design of science lessons (learning sequences regarding central scientific concepts) under the supervision of the educators' team, the implementation of these designs in their own classrooms and a common reflection on the designs and implementations done.

The rationale behind the interventions that form the second group of case studies seeks to promote a real exchange between teachers and researchers in a peer-to-peer approach that fosters an authentic reflection on teachers' practice. These teacher development programs also want to facilitate the cooperation within the school creating a sustainable teachers' learning community in order to promote science and mathematics teaching and learning improvement. When doing so, it is important to take into account real School situations and constraints, teachers' perspectives about their own difficulties and several other factors –internal and external- that may affect teachers' practices.

1.4 The process towards the recommendations

Findings and recommendations presented in this report are based on a meta-analysis of materials provided by previous research reports produced – both at the partner and at the consortium level - in the framework of the TRACES project including the cross-comparison of the national surveys (see Deliverable 3.1), the national case study reports (D4.1-4.6) and the report on the final workshops carried out during the TRACES conference (D5.1).

In a first step of the analysis, four researchers in the coordinating team independently reviewed the whole body of available materials, looking for emerging issues. Each researcher also produced a preliminary set of categories which could effectively organize the emerging issues. The categories produced by each researcher were then compared in terms of the related issues and a final set of seven categories was selected.

On the basis of the selected categories, a second-step review of the materials was carried out. This process, which again was conducted by the researchers independently, provided a set of preliminary findings coded in terms of the seven selected categories.

Based on these preliminary findings we drafted a first version of recommendations. For each of the seven categories, the recommendations are presented in both an extended form including all declinations and implications and a summarizing form. The first draft of the recommendations was circulated to all the partners and the final draft was developed by taking partners' contributions into account.

2 FINDINGS AND RECOMMENDATIONS

Research carried out in the framework of the TRACES activities over a period of almost two years in six countries provides a vast richness of insights that often go well beyond the research focus of the project, i. e. the relationship between research and practice in science education.

This is consistent with the project's research approach, aimed at identifying the actual constraints that influence research-based practice in science education and the actions developed in order to promote it and to address the project's research questions in terms of the complex system of factors involved. This applies in particular to the case studies, which constitute the core of the TRACES research programme.

Working with teachers in the framework of actions aimed at promoting research-based science teaching implied addressing, along with the more strictly disciplinary and pedagogical issues, equally fundamental questions such as those related to teacher pre- and in-service training, those related to the relationships among teachers and with the principal in the school, those related to the local context in which the school operates, such as the relationship with the territory and the local community, those related to the broader (national or regional) context such as the relationship with administrative and supervising institutions, the education policies, the official curriculum and summative assessment procedures.

These elements play an important role in teachers' work and have to be taken into account when designing transformative actions, that is, actions aimed at changing practice.

Change implies questioning consolidated practice and involvement in the broader debate on science education in a process of continuous reflection and professional development.

This process is promoted by interaction with colleagues in the same school and with external actors such as researchers in science education or teachers from other schools or educators from the informal sector.

TRACES research shows that teachers can largely benefit from increased opportunities of sharing their experiences and reflections in a group that works together identifying common issues and strategies.

Such groups include discipline related groups such as science departments of different kinds according to the school cycle, cross-disciplinary groups, cross-grade groups in the same cycle, cross-cycle groups in comprehensive institute etc.

Our findings support the growing consensus (see Stoll et al., 2006 for a recent review) that developing professional learning communities promotes change in teaching by supporting reflective practice and professional development.

In the schools where teachers are used to work in groups with colleagues from the same school or in networks with nearby schools, TRACES field actions found a richer soil for

common growth and effective exchange among teachers and with the researchers involved.

Issues which are recognized as shared by the group are more effectively addressed because self-confidence and motivation are strengthened. This also enhances teachers' attitude towards a perturbation to the ordinary work such as the one related to the interaction with the researcher. Moreover, a group of teachers who are able to establish common interests, needs, objectives are more likely to play an active role in creating or selecting targeted opportunities of professional development both in terms of structure and content. Such a bottom-up approach to the definition of specific professional development paths for different groups of teachers seems indeed promising in addressing the lack of coherence and systematicity which research identifies as one of the main issues in traditional professional development programmes (see e.g. Villegas-Reims, 2003; Guskey, 2002).

Another element emerging as crucial to the impact of research on practice is teachers' perceived relevance of research results to their everyday practice. Relevance emerges as a key factor in teachers' relationship to research-based stimuli aimed at promoting change as they may receive through official indications and curricula, research literature, training or other professional development programmes.

As any other research sector, research in science education is specialized in its language and norms, which are established and recognized by its reference community. In order to set up an effective dialogue with the different communities of practitioners, mediation is needed in terms of what content is identified as most relevant and what language is appropriate.

Past and ongoing European projects have addressed the research-practice gap by selecting research literature and presenting it in a more accessible language (as e.g. the resarch2practice[1] project, aimed at practitioners from the informal sector) or by disseminating well established research results through training (e.g. Pollen, Fibonacci, Inquire).

In most of TRACES field actions, researchers worked in schools with small groups of teachers trying to establish a participatory approach to the common work, in which researchers and teachers, notwithstanding the specificity of their competencies and roles, would cooperate as peers. This implied involvement in the decision making process regarding both structure and content of the action and co-responsibility in the implementation and evaluation of the programme.

In agreement with earlier studies (see e.g. Day, 1997) our findings suggest that if participants develop a sense of ownership of the programme, the programme is better received and more likely to have an impact on practice.

Analysis of TRACES field actions suggests that teachers' sense of relevance of the actions' content is strongly corroborated if researchers and teachers interact in concrete settings such as classroom activities with students. Shared classroom work strengthens teachers' trust in the researcher and the educational approaches the actions aim at promoting and demonstrates their relevance to everyday practice in that they are

[1] The project website is at http://www.research2practice.info.

confronted with real-world constraints. The classroom is perceived as the most reliable testing ground where the reflections developed at the researcher (or trainer)-teacher level can be evaluated in terms of soundness and applicability. By conducting activities side by side with the researchers, teachers are also more likely to develop a sense of confidence with regards to the promoted pedagogy and the necessary autonomy for incorporating related stimuli in their practice in the long term. Our findings suggest that this applies to both training programmes and to more general professional development programmes such as teaching experimentations or action-research programmes. As a broad corpus of research suggests (see e.g. Donovan et al., 1999; Newman et al., 1995), 'authenticity' promotes long-term learning and teacher learning should indeed make no exception.

The ideas of co-responsibility, ownership and relevance also emerged as key features in another structural element in a systemic view of school and teaching.

While some of TRACES case studies were specifically focussed on issues related to the interaction between the school, the community and the local socioeconomic and cultural specificities, also in other case studies and the workshops conducted during the final conference these proved to play an important role in the way science is taught at school.

Teachers involved in our research programme seemed to support the idea that the school should be seen as a collective construction in which teachers, pupils' families and other members of the community should be involved.

The idea of ownership and co-responsibility correspond on one side to seeing the school as an integral part of the community. An effective school is flexible to the needs and culture of the community in which it operates and with which a mutual recognition of norms, values, visions is needed. On the other side, the community should be seen as an integral part of the learning process of the pupils and it should take responsibility in what happens at school.

Teachers' work is most likely to have an impact on the students if the learning process is supported by the families and more in general by the local community and if the role of the school in the community is recognized and valued.

The support of the community appears even more decisive when the school is committed to experimenting innovative pedagogical approaches. In the framework of the TRACES field actions, teachers explored a number of different strategies aimed at involving the community while implementing research-based approaches to science education. Teachers' choices in terms of content also proved to be most effective when the content was recognized as relevant by the families and the local communities. For example, in rural communities in Argentina and Colombia, teachers involved in the TRACES field actions focused their work on content related to local needs such as running water or devices powered through solar energy.

Taking the local needs and interests and the cultural specificities of the community in which the school operates into account requires that the school's choices in terms of content and pedagogy enjoy a certain degree of freedom. In other words, that external constraints such as the national (or regional, according to the country's educational system) curriculum and assessment prescriptions are flexible to a certain degree.

A flexible national science curriculum requires that fundamental learning goals are identified, around which a more specific content can be selected at the school or class level according to emerging needs. Although there is growing research commitment aimed at identifying scientific core ideas and related learning progressions through the grades (see e.g. NRC, 2012) further effort seems to be needed in this direction. Impact on the educational policies, science curricula and teacher training appears very limited.

2.1 THEME 1: Cooperation among teachers

Even if teachers spend most of their working time alone with their students, the relationship with colleagues plays an important role in their everyday practice. Along with the tasks institutionally appointed to collegial organs such as the school or class council, the science department etc., teachers share their experience, beliefs, perceptions in many formal and informal situations. In smaller or larger groups, teachers take decisions about curriculum, pedagogy, assessment, in-service training and work organization that are then reflected in their classroom practice.

A large majority of the teachers involved in the TRACES large-scale national surveys referred to better opportunities of cooperation and exchange with colleagues as one of the most relevant factors for improving science teaching in their schools. When asked about sources of conceptual stimuli about teaching and factors that influence their practice, teachers in our sample mentioned interaction with their colleagues among the most important elements.

In TRACES field actions, researchers from each partner team involved groups of teachers from schools of all grades in activities focusing on research-based approaches to science teaching. In some cases the groups shared a history of cooperation and professional development, in other cases, the group involved teachers who were not used to work together on a deep level of reflection.

Analysis of our case studies suggests that the impact of the activities was influenced by the extent to which participants were able to share needs and visions and work together as a group.

In Italy's CS1 and CS2, two groups of teachers with comparable levels of experience in both practice and professional development were involved in similarly designed programmes. In both cases, decisions about both content and structure of the programme were taken collegially. While teachers in CS2, who were able to identify common interests and objectives and take decisions accordingly, expressed general satisfaction for the programme, those in CS1, who clearly were less used to shared reflection, found it hard to agree on suitable programme content and finally lamented the scarce relevance and limited effectiveness of the programme. Notably, the second group included teachers from two formerly distinct schools just recently united in a comprehensive institute.

Involvement in a professional development programme in interaction with external actors such as researchers or teacher educators or expert colleagues is – together with

specific pre-service training – the most relevant opportunity for teachers to be exposed to educational research.

Teachers who are used to cooperate with colleagues and able to establish common interests, needs, objectives are more likely to play an active role in creating or selecting targeted opportunities of professional development both in terms of structure and content. Such a bottom-up approach to the definition of specific professional development paths for different groups of teachers seems indeed promising in addressing the lack of coherence and systematicity which research identifies as one of the main issues in traditional professional development programmes.

As some teachers also highlighted, however, given the limited opportunities for professional development and more specifically in-service training activities, sometimes very few or even a single teacher in an entire school will be able to take part in such activities. This also partly depends on teachers' willingness to travel to another city or to invest part of their free time.

Also in this case, a group of teachers that make reflection and discussion an ordinary part of their work will be more likely to be able to take advantage of professional development experiences of single colleagues when they are shared within the group.

In any case, a practice of science teaching which is open to reflection and innovation based on stimuli coming, *inter alia,* from research results implies questioning ordinary work in light of an external stimulus that may – or may not – provide more effective approaches to teaching. In this regard, teachers in one of the final TRACES workshops interestingly referred to a 'perturbation' of an existing equilibrium.

TRACES research suggests that accepting such a perturbation requires strong motivation and confidence and that being part of a consolidated group of colleagues promotes both motivation and confidence. Sharing issues within the group implies opportunities for mutual support and for the exchange of competencies and experiences that may enrich and ease the work of all colleagues.

In many of the TRACES case studies, the presence of an external actor represented a catalyst in teachers' group dynamics, facilitating processes, promoting commitment, creating a virtual space for interaction to take place in situations in which even existing structures (for example the science department in the school involved in Italy's CS7) were not effectively exploited.

Teachers identified lack of time and appropriate organizational structures as the main barrier to cooperation with their colleagues. The opportunities for working together, for example conducting activities in the classroom or exchanging roles of conductor and observer, and for meetings in the broader group are limited and scarcely acknowledged. Notably, institutional pre- and in-service training programmes usually do not include cooperative work activities.

Teachers in Spain's CS1 (see e.g. p. 65) referred to ordinary work organization as a 'trap' that forces committed teachers to make up time to devote to shared reflection by renouncing to personal needs.

In Italy's eight case studies, researchers provided involved teacher with online community tools through the TRACES website with the aim of promoting exchange of

insights and materials. The tools included discussion groups, a repository of files aimed at the exchange of materials, and a blog tool to post comments about the development of the work, activities in the classroom, emerging issues etc. Although there was in fact very limited use of the tools, many teachers remarked their usefulness and suggested that resistance may be ascribed to the novelty of the medium and be easily overcome if the tools become integral part of the ordinary work.

Some teachers highlighted that the kind of work we were carrying out in the framework of the TRACES activities (see e.g. CS2) was indeed demonstrating the relevance of online tools such as repositories of materials and discussion forums to their teaching practice. It was also evident, though, that a key success factor was the fact that the materials collected and the discussions were strongly contextualized in that they were part of a wider programme including meetings in person, activities in the classes etc.

In the absence of preparation and awareness, even existing opportunities for teachers to meet and share reflection, such as the science department or the inter-class meetings often turn into service duties devoted to the accomplishment of bureaucratic tasks. Teachers in Italy's CS2 described a situation in which interaction tends to crystallize around tasks perceived as bureaucratic requirements such as the yearly programme[2] development and there is indeed no real dialogue on deeper elements relevant to the teaching practice.

Prospective science teachers involved in pre-service training in Brazil's CS3 emphasized the relevance of cooperating in communities of practice and reflection groups and suggested that students accessing the courses should be selected according to their interest and availability to share experiences and reflection with colleagues.

Many teachers pointed out that, for the interaction to be effective, the level of the discussion should address fundamental questions such as visions of education and of science education in particular. Teachers in Spain's CS1 considered the opportunity to share reflections on science teaching in a research approach that involves deep analysis and evaluation of classroom activities with the aim of informing practice. The process seemed to be promoted by collaborative design of classroom activities, which provides a concrete common ground on which to share reflection on both disciplinary and pedagogical aspects.

The possibility of structuring the curriculum according to specific school or classroom needs was particularly valued by teachers involved in the TRACES research. This was for example the case in Brazil's CS2 (see e.g. p. 89), in which official indications granted sufficient flexibility for mixing classes into larger groups of students for teachers to carry out classroom activities in teams. Colombian (see e.g. CS2, p. 111) and Argentine teachers emphasized the need for national curricula to be general and flexible enough to adapt to local cultural and socioeconomic specificities with regards to the local community or the single class (see also THEMES 5 and 7).

Discussion on fundamental aspects such as the vision of teaching, the structure of the planned and implemented curriculum and students' assessment emerge as particularly relevant when teachers from different cycles interact. While official indications often

[2] As opposed to *curriculum,* the term *programme* refers to a mere list of subjects to be covered. Every year, teachers are required to devise a programming for the next school year.

emphasize the importance of continuity along cycles (verticality), school systems often display fractures in approaches related to different teacher preparation and selection, curricular structure, assessment procedures etc. Opportunities for teachers from different cycles to meet are also very limited. In Italy, recent reform is promoting the formation of comprehensive institutes including kindergarten, primary and lower secondary cycles.

For teachers in newly formed comprehensive institutes (see e.g. Italy's CS1), involvement in cross-cycle boards such as the science department represent both a challenge and an opportunity for sharing reflection about verticality issues and exploiting one another's specific competencies. In Italy's CS8, differences related to the vision of the role of the teacher and his/her responsibility with regards to students' learning seemed to represent a serious barrier in understanding how work in a higher cycle may build upon development in the lower cycle.

Sharing reflection and discussing within a group implies sharing doubts, difficulties, limits, and exposing one's own practice to public criticism. This is a demanding process and requires favourable conditions to be promoted. In particular, mutual observation of classroom practice, which many teachers referred to as an effective peer-to-peer exchange with their colleagues (see also THEME4), may represent a demanding commitment for some. In Italy's CS8, teachers showed widespread resistance to being observed while teaching and more generally there were few cases in which teachers agreed to be observed when simply asked to do so. When mutual observation was instead explicitly supported and established as an integral part of the programme (as for example in Brazil-CS2, Colombia-CS3, Spain-CS2) teachers expressed great enthusiasm for the process.

Some teachers also pointed out that sometimes consolidated groups sharing common visions of education, along with practices of communication and interaction, might as well be subject to stagnation because inclusion of external stimuli is limited. In Spain's CS1 (see e.g. p. 68), a group of teachers from different schools with a long history of cooperation and common reflection on issues emerging from their everyday classroom practice emphasized how sharing a common approach to teaching and a consolidated relationship with academic research in education may represent a barrier to including other colleagues in the group.

RECOMMENDATION 1

Cooperation and sharing represent fundamental components in teachers' practice and professional development. Systemic elements such as pre- and in-service training, organization of work time and spaces, documentation and communication tools should be so designed as to promote a culture of cooperation and sharing among teachers in each school.

TRACES research suggests that cooperation with colleagues is precious for teachers' work. It promotes reflection on practice and therefore teachers' professional development. By creating a sense of belonging to a group with common objectives and issues, it strengthens teachers' motivation and confidence.

In working and reflecting cooperatively with their colleagues, teachers should be committed to sharing and questioning crucial elements of their practice, such as a vision of education, the role of the school in its territory and community and epistemological and methodological aspects of the pedagogy of the disciplines.

Policies should recognise cooperation and sharing as a structural part of teachers' practice and provide appropriate resources in terms of time, spaces and training.

Provision of time resources calls for a reorganization of teachers' work time as to include activities such as cooperative planning, reflection, assessment and teaching. Sharing is also promoted if teachers are encouraged to document their activities and produce materials that can be accessed and used by colleagues.

Training also plays a crucial role in promoting a culture of and nurturing competencies for cooperation and sharing. Teacher preparation and professional development programmes should include such activities as team work, mutual observation, shared planning and reflection.

Research should further investigate into the opportunities of cooperative practice and shared reflection and provide support on how to document teaching activities and produce usable materials.

The use of online community tools, although still hindered by some resistance due to the novelty of the medium, represents therefore a promising contribution to teachers' opportunities of communicating and sharing experience, reflection and materials and should be promoted. Teachers should be involved in the development of more effective and usable online community tools to be then provided to all schools.

2.2 THEME 2: Exploiting existing resources

The question of limited resources available to schools, in terms of personnel, materials, opportunities for in-service training etc. is perceived as paramount by most teachers involved in TRACES research. In the large-scale national surveys, teachers referred in particular to a higher provision of material resources, laboratorial facilities, connection to the internet as relevant factors for improving science education. TRACES research suggests that important resources exist in the school system which it is sometimes difficult to identify, acknowledge and effectively exploit.

Many teachers and groups of teachers develop rich professional knowledge through practice and in-service training. Many teachers have consolidated competencies in specific areas such as laboratorial activities, disciplinary content, pedagogical approaches, interaction with the informal sector, involvement in school- or university-based research programmes and may play the role of experts and support their colleagues' practice and professional development with limited impact on schools' budgets.

TRACES researchers found that expert teachers may contribute significantly to the development of the entire school when they take on roles of leadership in specific areas (Spain's CS1, see e.g. p. 67) or when their working time is organized in such a way as to enable them to support their colleagues, for example by advising about the design and implementation of laboratorial activities (Italy's CS7). In Italy's CS5, the entire development of a peer-to-peer training programme was put at risk when the leading teachers were forced to discontinue their commitment due to personal problems.

In Brazil's CS2, researchers found that the teachers in the school involved took up the role of leading actors in promoting innovation by making the best of the latest policy reform allowing for greater freedom in organizing classes and work around more cross-disciplinary conceptual nodes.

A relevant insight emerging from TRACES case studies involves the issue of how teachers may capitalize on their experience in classroom practice and professional development so that the experience of each individual can serve as a resource for himself and the teaching staff as a whole (see also THEME 1).

In particular, the problem of how to document experience and produce materials which are 'usable' by other colleagues and how to share these materials seems complex. According to the discussions in Italy's CS2, teachers identified the two fundamental elements for sharing and fruitful exchange of experiences in the documentation of their work and the production of usable materials, and the meetings in person in which one gets the real feeling of what people need and why certain materials might be useful for future activities.

Cooperation among teachers from different cycles seems particularly effective since competencies are often complementary. For example, teachers from the primary cycle are usually more competent on issues related to pedagogy and classroom management while teachers from the secondary cycles may be more competent in disciplinary content. TRACES researchers found that teachers practice can effectively benefit from cooperative activities such as shared planning and reflection (see e.g. Italy's CS7). In the comprehensive institute involved in Spain's CS1 (see e.g. p. 148), researchers encouraged teachers from the primary cycle to exploit the science laboratory facilities in their institute, formerly only available to secondary cycle students. The process resulted in a permanent change of the internal regulation for accessing the laboratory.

On the other hand, the opportunities available to teachers in comprehensive institutes may be missed when teachers tend to consider their students' learning along the different cycles as separated in self-consistent blocks, rather than a consistent, coherent long-term path (see e.g. Italy's CS8, p.204) or when they are not able to develop a shared vision of founding questions, such as whether the school curriculum should or should not refer to methodology besides contents (see Italy's CS1, p. 43)

RECOMMENDATION 2

A rich patrimony of experience and competencies related to science education exists in all schools and should be valued and exploited. Many teachers can be recognized as experts with specific competencies and can effectively contribute to their colleagues' practice and professional development as well as to the broader science education research debate. In particular, cooperation and sharing among teachers from different school cycles and scientific disciplines should be promoted.

Findings from TRACES' extensive interaction with schools highlight the existence of a rich patrimony of experience and competencies which can be precious for supporting further development. On the other side, teachers are not seen as the ones in charge for making experiences transferable to different contexts: a role which is most commonly appointed to scholars.

Effort should be put in making explicit, accessible and usable the pedagogical and didactic knowledge, as well as instructional materials, produced in schools through everyday practice and individual and shared reflection.

In particular, specific disciplinary and pedagogical competences developed by many experienced teachers through yearlong practice and training should be valued and exploited in supporting colleagues in their own practice and professional development.

Some teachers should be appointed specific functions in their schools, such as responsibility for the science laboratory and training and advising colleagues in developing and implementing laboratorial activities related to specific science content.
Experienced teachers should be involved as educators in teacher preparation and professional development programmes (see also THEME 4.).

The recognition of experienced teachers should not be internal to the school's teaching staff but imply a broader process involving external actors such as the local community, researchers and other experts (see also THEME 3 and 7).

Some elements of the school system also structurally contribute to providing teachers with different competencies. While primary school teachers are more extensively trained and more experienced in pedagogy, secondary teachers are more competent in content knowledge related to the different scientific disciplines. Cooperation and sharing between teachers from different school cycles and trained in the different scientific disciplines should be promoted as an effective and inexpensive strategy for exploiting existing resources for enhancing teachers' pedagogical, disciplinary and cross-disciplinary competencies.

Alongside scholars and educators from the non-formal sector, teachers should be involved as active participants in the educational research debate, to which they may contribute with specific competences and experience.

2.3 THEME 3: Cooperation between teachers and researchers

Teachers very broadly expressed great appreciation for their interaction with academic researchers. In particular they remarked in several circumstances and in different contexts the advisability of setting up stable communities of practice formed by teachers and researchers cooperating as peers so that each member, by means of active participation, provides meaningful contribution for each other's work. Some teachers (Spain, CS1, p. 152) suggested that this kind of interaction should be compulsory and regular.

In several contexts, the interaction between teachers and researchers seemed particularly effective when it involved direct participation of researchers in teachers' activities, especially classroom activities. This occurrence allowed actual exchange between the two groups, moving from a shared practice that played the role of common ground within which people were able to construct meaning. The interaction between teachers and researchers appeared less effective when these participative modes could not be established (see e.g. Italy's CS1, p. 49).

In many cases the researchers' presence played a relevant role of catalyst, facilitating reflection and sharing within the groups of teachers. In some situations, the researchers' action supported the development of potentialities which were already present in the schools but scarcely developed otherwise.

Several results from research in science education were considered hardly understandable by the side of teachers, because they too weakly refer to real situations. Sometimes research results are considered useless, because they reformulate taken-for-granted ideas in a more complex language. Actually, some teachers (Italy, CS7, p. 187; Spain, CS3, p. 138) expressed scarce interest in research results as they are ordinarily published, because they turn out scantily accessible and usable. In other cases, however, teachers appreciated the possibility of accessing literature in the field of science education through the researchers' mediation (see e.g. Spain's CS3).

Some teachers expressed a strong confidence in the way they work and in the implicit assumptions underlying their choices. On the other hand, almost all teachers, both those who feel strongly self-confident and those that do not, referred to the necessity of building large theoretical frameworks, characterized by strong key-ideas, to be used as reference frameworks for planning and conducting classroom activities. These frameworks could be either autonomously outlined by groups of teachers in a school (Italy, CS7, p.183; Brazil, CS3, p.104) or elaborated by groups of teachers collaborating with researchers (Spain, CS3, p.145; Italy, CS2). According to a widespread idea, the production of such a framework should entail a rethinking of the structures of scientific disciplines in a didactic perspective.

RECOMMENDATION 3

School is the most significant place where research on learning and teaching can be developed. In order to make research sustainable and effective, teachers should have opportunities to meet and share ideas and practices with external actors, engaged in research in the field of science education. This kind of research should aim, on the one

hand, at producing general frameworks of reference. On the other hand, it should aim at developing proposals feasible and compatible with forms and features of school practice.

School is the main and most significant common ground for teachers and academic researchers in science education to work together with their different expertises and sensibilities.

Actual improvements in science education can be achieved through the interaction among teachers and researchers in communities of practice, where each one – by means of active participation – provides meaningful contributions to each other's work.

Differently from teachers, academic researchers in science education devote most of their time to reflection and analysis, without practical concerns such as the management of classes, the relationship with parents etc. Therefore, they should be fit to give a relevant contribution in order to outline, along with teachers, a theoretical framework for the design and development of science education activities and assessment strategies.

This framework should be, on the one hand, general enough to guarantee that teachers will be able to use it autonomously according to their needs, interests and possibilities as well as the specificities of the contexts in which they work (see also THEME 2). On the other hand, the framework should be structured enough in order to give sense and coherence to the teaching practice.

Therefore, teachers and researchers in science education should be committed to make explicit the features of scientific knowledge (in its forms and in the way it is produced), according to the contribution those features can offer to people's cultural development and considering their relationship with the cultural background within which science education is carried out.

A mediation seems therefore necessary between science as a specialistic cultural production and educational needs. The efforts aimed at an effective mediation should provide a reshaping of science according to what and how to teach in schools. In this sense, reshaping of scientific knowledge should be a central commitment for research in science education.

This reshaping should encompass several levels. A reorganization of the structure of scientific disciplines is necessary in order to clarify the relationship among the related conceptual, formal and operational aspects. A central point concerns the possibility of recognizing how these elements comply with the way people ordinarily understand, use language and act in their everyday life. In this perspective, a special emphasis should be put on the relationship between natural language, with its rules, meanings and uses, and the same features of a scientific view, with a particular focus on the role played by mathematics.

A reconsideration of disciplinary structure should therefore necessarily take into account the way people understand and learn, so that cognitive modelling plays a relevant role as a tool for bridging between individual and culturally stabilized knowledge.

The design and the development of science education activities should be grounded in research findings on learning dynamics and cognition. Since cognitive models can – more or less implicitly, more or less naively – inform teaching strategies, efforts should be made in order to highlight the specific contributions cognitive sciences can provide with regards to issues of didactic mediation, making explicit the implications and the perspectives of the different possible approaches.

A regular interaction between teachers and academic researchers in a shared context of work and reflection can provide opportunities for taking advantage of respective contributions to the development of effective practices in science education. Results from research in science education seem to be scarcely appealing for teachers because they are often poorly accessible and usable. Teachers often remarked that research findings are hard to understand because they are too weakly referred to real situations or useless because they say what is already known in a more complex way.

Researchers interventions at school should be based on a participative cooperation model in which all actors work together as peers and decisions are taken collegially. It is important to be committed to building a common language and identifying common needs and aims.

In order to effectively impact practice, cooperation should not be limited to lecturing and training at the teachers-researchers level but include shared work in the classes, where concrete issues can be addressed and relevance of the experimented approach demonstrated.

Long-term experimentations carried out by teachers and researchers together should be promoted. This kind of research activities supports the development of meaningful educational activities based on more reliable evidence about their long-term effectiveness.

Researchers can play a role of catalyst within groups of teachers committed to shared reflection about their practice and experimentation of research-based approaches (see also THEME 2). In this case, researchers should be able to support teachers in ordinary educational contexts applying a flexible approach in which the intervention can be developed according to participants needs and interests.

Besides collaborating with single groups of teachers, researchers should also address more general issues related to educational systems (see also THEME 6). Researchers should provide contributions about the way preparation, in-service training, curricula and evaluation strategies and procedures can be coherently developed. A growing body of research suggests that a promising approach is emphasis on cross-cutting concepts and disciplinary core ideas and learning progressions across grades (see also THEME 5).

2.4 THEME 4: Teacher training

The direct and participative involvement of teachers in training programmes seemed to play a very relevant role in TRACES field actions. Actually, teachers in different contexts acknowledged a great usefulness of training activities in which they were involved in a participative form. Training sessions were particularly appreciated when they were centred on dynamics that typically develop in the ordinary practice of science teaching and learning. These activities were considered effective and motivating because they promote teachers' commitment to the development of innovative paths in science teaching.

In several contexts it emerged that the training programme can be scarcely meaningful and badly received by involved teachers if it imposed top-down. Generally, groups of teachers expressed the need of autonomously deciding forms, ways and contents of in-service training activities. The possibility of setting up training environments based on peer-to-peer interaction was broadly acknowledged as relevant.

A certain difficulty was pointed out in planning and conducting activities in science education which are structured in a flexible enough way in order to allow for a free explorative practice and a meaningful production of discourses, starting from ordinary pupils' knowledge. This difficulty was mainly expressed by primary school teachers (e.g. Italy, CS2, p.69). According to the teachers, this is related to a difficulty in managing specific disciplinary content (e.g. Italy, CS4, p. 119; CS8, p. 210). Many teachers referred to inadequate training, both pre- and in-service, as the main factor in their lack of confidence.

Some teachers expressed a considerable difficulty in managing the divergent ways pupils can adopt when they approach specific scientific content. Many teachers explicitly requested that some training activities be devoted to support and develop their capability to manage this kind of situations, in order to allow for a significant inclusion of different contributions which pupils could bring to the work sessions at school.

Some teachers attributed great relevance to training programmes which enable them to elaborate an autonomous pedagogical view in which to frame science education activities (see e.g. Colombia, CS1, p. 77). Training seemed to be more effective when teachers were able debate and re-elaborate curricular content and instructional materials (e.g. Israel, CS1, p. 22).

It seemed that useful training programmes should include elements concerning the ability of understanding the connections between what happens at school and the ways people live, understand and learn. A need for training programmes to include insights coming from social and anthropological studies emerged in several contexts both explicitly (Colombia, CS1; Argentina, CS2) and implicitly (Italy, CS7, p. 192). A need also emerged for training on elements related to cognitive issues, as well as reflections about the relationship among mathematical, scientific and linguistic knowledge. For example, teachers in Spain's CS2 (see e.g. p. 104) emphasized the value of introducing a specialist language along with the use of the related concepts in classroom activities. Other teachers (Brazil, CS1, p. 66) considered the relevance for students to autonomously produce scripts in order to reorganize inquiry-based activities. This task also seemed to

improve students' linguistic skills, as it was pointed out by teachers teaching classes with significant numbers of students with migration background (e.g. Italy, CS3, p. 102).

In different contexts, a view emerged that in-service training should have the actual teachers' needs as a starting point. Therefore, the training experiences should be designed weighing and integrating in an equilibrated manner both theoretical and practical aspects (Israel, CS2, p.60), so that teachers can recognize the possibility to use, in the ordinary practice, what has been developed within the training activities (Spain, CS1, p.64). At the same time, teachers should be enabled to compare contents and forms of training experiences with their personal beliefs about science education (e.g. Brazil, CS2, p.97). Moreover, it seemed that the actual possibility of making sense of training activities lies in the fact that teachers can recognize the opportunity to explore point of views that are wider than those they usually consider, but tracing back to already consolidated knowledge and experience (see e.g. Italy, CS2, p. 73).

TRACES research suggests that training activities that reflect classroom activities in their structure are perceived as relevant by science teachers. This opinion was shared by both groups of teachers involved in the development of field actions and different actors that took part in workshops during the final conference. In particular, great relevance was attributed to training activities which actually encompass practical and laboratory work. For what regards in-service training, this was related to the fact that such activities seem to enhance teachers' confidence in managing the work with pupils (e.g. Spain, CS3, p. 147). For what regards pre-service training, participant teachers pointed out that such activities enabled them to imagine themselves as teachers and project themselves in actual situations (see e.g. Brazil, CS3, p. 121).

In many cases, mutual observation and analysis of classroom activities emerged as effective tools for teacher training. These two practices seemed to enable teachers to enhance their awareness of their pupils' long-term improvements while reconsidering the short-term impression that the teaching might be ineffective (Spain, CS3, p. 103). Also, the observation of classroom sessions undertaken by experienced teachers was perceived as very useful, in that it demonstrates the effectiveness of specific approaches to instruction (Israel, CS1). Another relevant element for the training activities seemed to be the sharing among people in form of discussion, which enables trainees to have the opportunity of re-constructing in a meaningful fashion their pupils' experiences, situating their teaching in an broader frame (e.g. Colombia, CS1, p. 80).

In several cases, teachers attributed a considerable relevance to different forms of acknowledgment of their participation in in-service training, not necessarily in terms of retribution. Trainee teachers aiming at becoming trainers seemed to develop a particular sense of effectiveness compared to other colleagues in their training group (Spain, CS1, p.63).

RECOMMENDATION 4

Teacher training as a continuous process should be mandatory. Peer-to-peer training is represent an particularly effective and economic resource and should be more extensively exploited. Training programmes should include activities related to the planning, evaluation and analysis of teaching/learning dynamics as they actually develop in the classroom.

Effective training programmes should aim at providing teachers with tools that enable them to develop their work according to a desirable profile of autonomous and responsible teacher (see also THEME 2). Training can be provided, on one hand, by colleagues, if appropriate structural conditions are guaranteed by the system. On the other hand, training should be provided by experienced trainers in science education who actively engage in ordinary work with classes in addition to lecturing.

As a continuous and long-term process, training should move from isolated, short-term, fragmentary and incoherent initiatives to become an on-going teacher and school guided process of supported reflection aimed at informing practice.

Professional development opportunities should, on the one hand, be embedded in ordinary teachers' work, and on the other, that they should be linked to real classroom practice, adapted to the purpose of addressing the specific issues of teachers involved. In this perspective, teacher professional development should become part of teachers' professional practice and therefore be mandatory.

The direct involvement of the trainers in classroom activities is an important factor in making the training more meaningful and relevant for the involved teachers. Training activities, however, should include both action and reflection on what actually happens at school, in order to provide teachers with tools usable in and compatible with real work contexts. At the same time, effective training activities should encompass sessions devoted to mutual observation and sharing of different competencies in a group of peers.

An effective training should make involve a commitment to outlining a reshaping of scientific knowledge in a pedagogical perspective (see also THEME 3). Relevant elements of a training programme should be devoted to reconsidering disciplinary content taking its epistemological implications into account and developing insights about how scientific ideas form as suggested by their historical development.

A special attention should also have to be paid to cognitive dynamics, with their implications for what concerns the pedagogical mediation and the evaluation. In this view, also the information and communication technologies should be reconsidered, taking into account their peculiarities, with regards to the way knowledge is built through their use. Their opportunities to produce specific operations and representations should be analysed in training sessions, as well as the cultural elements they embody in their working.

It also seems relevant for training to address broader issues, such as those covered in other THEMES in this analysis. Along with cognitive and epistemological elements, for example, insights from anthropological and socio-cultural studies related to teaching/learning should be an integral part of teacher preparation and in-service training.

Training should also provide teachers with tools for documenting, analysing and evaluating their activities and the teaching/learning process developed in their classes. Direct and participative involvement of teachers may also play a fundamental role in order to produce effective and motivating dynamics in training activities. Many of

teachers involved in the TRACES field actions attributed great relevance – in terms of effectiveness – to participative training environments.

Training contexts should be characterized as situations where teachers are directly involved and participate as active subjects, confronting with actual dynamics typical of teaching/learning processes and dealing with the specificity of science knowledge, as well as with the contribution it can give to the pupils' formation.

Moreover, another factor emerging as relevant involves engaging teachers in situations that are similar – for treated contents and educational strategies – to those they are expected to create with their students. The idea is that the way training is developed should reflect the way one thinks science and mathematics have to be taught in the classroom.

In this view, training sessions should encompass a set of activities that involve theoretical framing, laboratory experimentation, multi-representation and explanation of what happens, which are mutually intertwined and not hierarchically structured.
Nevertheless, training activities have to necessarily include elements devoted to develop abilities and sensibilities concerning the meta-cognitive analysis, playing a fundamental role in the managing of groups engaged in learning experiences.

Many teachers in the TRACES field actions highlighted a difficulty in relating to students' divergent ways of thinking and approaching scientific problems. Training programmes may address this issue explicitly through the use of cultural tools – as provided by research and reflection in several fields - as lenses which enable to re-consider and interpret teaching strategies and learning dynamics.

Policies establishing in-service training as mandatory will only be effective if they are accompanied by an actual enhancement of the training opportunities available. Moreover, enabling teachers to autonomously determine their in-service training path and negotiating the content and structure of the training programmes they undertake can contribute to address the issue of episodic, fragmentary and incoherent training experiences as identified by research on "traditional" in-service training.

The actual possibility for teachers to make sense of science education activities and strategies as they are suggested by research seems to lie in the grade of proximity between the promoted pedagogy and the way teachers intend and carry out their work, as well as their disciplinary and pedagogical knowledge and expertise. This suggests that effective training activities should have their starting point in the way participants actually work and aim at offering a progressively enlarged perspective. Teachers involved in field actions based on this model expressed higher confidence in their professional development through the training and sense of relevance of the training to their teaching practice.

2.5 THEME 5: Relationship between local and central

Stakeholders involved in the TRACES research programme broadly expressed the need for a larger involvement of the different actors, at the local level, in open debates about pedagogical issues concerning science education and related specific actions to be undertaken. This position appeared to stand out against initiatives imposed top-down, which are perceived as inadequate with regards to taking local needs into account.

In several contexts, the relevance of socio-cultural issues is so strong that it significantly constraints teachers' choices, as well as those of entire schools, for what concerns both the implemented curriculum and pedagogical and instructional aspects of everyday practice. This emerged in both European urban, middle/low-income contexts (Italy, CS7; CS8) and, in Latin-American contexts with limited access to resources (Argentina, CS2) or exposed to conditions of environmental degradation (Colombia, CS3).

It was very broadly requested that the structure of curricula and related evaluation criteria should be designed in order guarantee sufficient flexibility for teachers to be able to adapt them to the specific needs of their local contexts. Teachers in our case studies suggested, in particular, that standardized tests should rather be aimed at providing a picture of the global situation of a school, or of a school system, than being used for students' assessment (see e.g. Italy, CS7, p. 182). Furthermore, some teachers pointed out how the introduction of standardized tests forces to implement a broader curriculum in the attempt of covering all subjects included in the national curriculum increasing the tendency to cover too many subjects in scarce depth (see e.g. Israel, CS2, p. 60), a tendency stigmatized in research literature as the mile-wide, inch-deep curriculum.

In some cases, evident tensions and divergences were recognized between teachers seeing education as aimed at the development of critical thinking and responsible citizenship, and policy makers interested in fostering the development specific skills aimed at guaranteeing productivity and economic competitiveness of the nation (Israel, CS3, p. 81). In the same way, tension were highlighted (Colombia, CS3, p. 165) between general ideas about science education as they promoted by research and national curricula and the specific contextual needs as identified by the teachers in their everyday practice.

In some case studies, high school students seemed scarcely involved in a debate concerning the social role played by science education. In some contexts, students picked out basic competences in mathematics and science – those covered in primary school - as the only ones related to their everyday life (e.g. Italy, CS5). At the same time, however, they seemed scarcely interested in the learning in that area. On the contrary, in situations in which students were involved in a debate on the social role of science education, students were participated more actively in their learning at school (e.g. Colombia, CS4; Argentina, CS3).

RECOMMENDATION 5

Curricula and evaluation strategies and tools should be designed in order to enable teachers to take local specificities into account. Curricula should be flexible enough to be adaptable to needs related to local educational contexts. Standardised tests should be aimed mainly at gathering data that support schools in evaluating how their students' performance are related to the national standards and at revising general educational policies.

A structural tension exists in the school system between the central and the local dimension. In their everyday practice, science teachers are committed to finding an effective compromise between taking their students' specific needs and interests into account and complying with national indications about the contents and pedagogy in the science curriculum. Implemented curricula in each specific class should not neglect local factors such as student families' and the broader community's socio-cultural specificities at each time in their historical development.

Another structural tension between the central and local dimension is related to the gap between science education research and actual teaching practice. Researchers should commit to the development of an intercultural approach to science teaching, proposing a vision of scientific knowledge which does not discredit, invade or discriminate the local culture. It seems furthermore important that teachers be involved in this process in order for the research to have an actual impact on practice.

In order to manage the integration of the central and local dimension, schools (and teachers) need to enjoy a sufficient degree of flexibility in designing and programming educational activities, in choosing teaching approaches and methodologies. Curricula should be designed in order to guarantee such flexibility, identifying key learning objectives that are general enough to be adaptable to local needs. A promising line of development in this direction, as suggested by research, is to base national curricula on disciplinary core ideas and interdisciplinary crosscutting concepts to be addressed along long-term learning progressions across all grades.

Assessment strategies significantly inform educational strategies adopted in schools. The use of standardised tests to assess students' performances may represent a further barrier to the integration of the central and local dimension in science education. Rather of being used as official assessment tools, standardised test should be intended to provide schools with general indications highlighting possible learning difficulties of their students. Low performance in the tests should result in enhanced support offered to the schools in terms of material resources and teaching staff.

Standardized tests can be used with the aim to provide schools an tool for evaluating effectiveness, issues, barriers and devise strategies. Self-evaluation activities may promote teachers' sense of ownership and responsibility in their work in agreement with a broader vision of autonomy as addressed in other THEMES in this analysis.

Teachers should be granted a more active role in the debate determining the choices made at the central level about the structure of curricula and assessment tests. A possible strategy to pursue this aim is the formation of consulting commission/boards involving teachers together with other relevant actors (principals, supervisors, curriculum developers, researchers, school administrators).

2.6 THEME 6: Long-term sustainability

TRACES research suggests that initiatives promoting innovation and experimentation in science education are more likely to involve entire schools and large numbers of teachers when they are sustained by those responsible for educational policies because they are perceived as structural by the teachers (see e.g. Israel, CS3, p.84). In the cases in which this institutional support is lacking, the results obtained by this kind of initiatives seemed very limited.

Particularly favourable circumstances for the development of effective innovation initiatives emerged in those cases (Argentina, CS1, 2, 3) where educational authorities were committed to follow and coordinate the development of the actions through the work of supervisors having a school teaching background.

On the contrary, national initiatives perceived by teachers as unsuccessful were often characterized (Spain, CS1, p. 67; Italy, CS7, p. 178 and CS8, p. 203) by an initial enthusiastic impulse not followed by the needed institutional support promoting processes of cooperation among schools and with other actors involved in educational experimentation, such as researchers or educators.

In order to implement initiatives aimed at promoting innovation of science teaching in their schools, school principals highlighted a need for adequate financial support and the actual possibility of suitably reorganizing teachers' timetables (Israel, CS2, p. 60). In fact, significant experiences were developed in those cases in which school administrators provided teachers with an actual recognition of the workload related to participation in special initiatives (Spain, CS1, p. 51). These enabled them to grant teachers a longer-term basis in the implementation of the initiatives, incorporating the innovation activities in teachers' ordinary work-plan and providing specific professional development courses connected to the proposed experimentations.

Producing documentation materials about the classroom activities was recognized by many teachers, including those involved in training courses (Colombia, CS2, p. 97), as a very meaningful way of setting up a shared reflection and evaluation of their work. Nevertheless, difficulties emerged concerning the access to materials produced and circulation of the related reflections made by colleagues, even in those cases in which this practice seemed to be well-established among teachers (Italy, CS2, p. 67).

In some cases (Spain, CS3, p. 137), a difficulty emerged among the teachers to inscribe their work within a more general reference framework shared with their colleagues, going in the direction of defining a vertical curriculum covering their students' entire school path. Even in those cases (Italy, CS1 and CS8) in which the development of a vertical curriculum (including grades from 1 to 8) was sustained by official indications, teachers expressed their difficulty in sharing a common framework with colleagues teaching in different school grades.

Some case studies suggest that when teachers recognize themselves as intellectuals having full responsibility in choosing the cultural directions framing their teaching practice they are more likely to set up significant educative experiences (Colombia, CS1, p. 62). These of teachers expressed the need to share with their colleagues the

construction of a theoretical framework for their practice, claiming the need for a wide decisional freedom based on their awareness of the socio-cultural context in which they operate (Italy, CS7, p. 138) and on their capacity to link classroom activities with the spontaneous knowledge built by their students in their everyday life (Colombia, CS4, p. 209).

RECOMMENDATION 6

Schools should be enabled to autonomously develop educational experiences that are shared within the school itself in a community dimension, giving continuity to the educational choices made and making the school capable to consider and exploit the opportunities of support offered by the school system and the interaction with external actors.

Teachers' self-confidence in the possibility of autonomously undertaking paths and experiences in science education which are meaningful for their students (and for the teachers themselves) is key success factor in effective science teaching. Teachers' work should be framed according to general, fundamental guidelines which leaving teachers free to autonomously develop specific educational paths in their classes. Teachers should be provided adequate tools (disciplinary knowledge, expertise in planning, evaluation strategies and criteria) to be able to effectively pursue their educational objectives and be flexible enough in undertaking their strategies. Sharing this approach to teaching practice in a community dimension within the school can promote a meaningful process of continuous revision of the teaching strategies.

A prerequisite for any widespread improvement of science teaching is the establishment of a stronger coherence among the fundamental elements of the school system: teacher preparation, curricula, continuous professional development and evaluation strategies.

A carefully balanced science curriculum combining core disciplinary ideas with the broader content and everyday experience may represent a general framework for guiding the development of school teaching. This also offers teachers a common ground for continuous dialogue about scientific ideas, disciplinary aspects and methodological issues with a strict connection to their actual practice. The science curriculum should be flexible enough to enable teachers to adapt it to the needs emerging from this process of reflection about their work.

Schools should be strongly committed to producing materials documenting the educational experiences undertaken by their teachers. Documentation should be shared among the teachers and continually revised and reused in the classes. This also provides criteria on the form and contents of "usable" documentation. Documentation should explicitly refer to the framework within the activities have been developed and to the criteria used to evaluate them.

The continuity of the educational choices made in each school is can be supported by appointing some teachers with specific institutional roles in coordinating the sharing of documentation materials. This also enhances teachers' opportunities to work as a community and facilitates the integration of new teachers joining the school staff in the community.

The construction of a community dimension within the school also enhances teachers' ability to identify opportunities for external support (in-service training, extracurricular activities, classroom experimentations) according to what best suites their professional development needs. This approach also supports the interaction between the school and the broader school system and external actors. The interaction should be mediated on the small-scale level by institutional figures such as supervisors in order to exploit resources available at the local level and promote the development of collaborations within local networks of schools and other institutions (universities, teacher training institutes, science centres and museums, other associations and centres involved in science education).

2.7 THEME 7: Relationship between school and society

In a number of contexts, a lack of active involvement in the development of the learning experience by the side of students (especially those in higher grades) emerged. Students often perceive scarce relevance in both the content of school topics and the way school activities are carried out. Italian 12-graders (Italy, CS5, p. 141) manifested rather naïve visions of the social function of science literacy, assigning actual relevance to elementary competences and skills only, while perceiving more complex disciplinary contents as part of a self-referential scholastic knowledge difficult to relate to everyday experience.

Many teachers highlighted (see e.g. Brazil, CS1, p. 63) that the effectiveness of the teaching/learning process is enhanced when the formulation of problems and questions moves from a teacher-centred to a student-centred approach. For these teachers, this implied explicitly discussing with the students the relevance of the topics proposed as connected to the actual socio-cultural context they are part of.

This approach seems to be effective in that it promotes students' active involvement and sense of ownership of the scientific knowledge they are expected to develop. Also, it seems to enable students to develop a sense of responsibility towards the evolution of their knowledge and to consequently recognize themselves as actors actively participating in the life of their community (see Colombia, CS4, p. 20). This kind of perception about school science is strongly contrasting with the ideas expressed by the abovementioned Italian students (Italy, CS5, p. 141) who seemed to perceive scientific knowledge as elitist and socially discriminating as a consequence of the difficulty in accessing its specialistic language.

In some case studies (in particular two case studies involving schools based in middle-class areas of European cities, see Italy, CS6, p. 159; Spain, CS3, p. 120), students' families attention towards school activities was perceived by teachers as an undue pressure interfering with their work. Teachers remarked that they sometimes feel obliged to make particular educational choices in order to meet parents' expectations. In other cases, teachers mentioned how their will to keep an autonomous way of managing school activities can cause conflict with the parents. On the contrary, direct involvement of students' families in the educational experimentations carried out at school (Spain, CS2, p. 115) seemed to promote parents' recognition of teachers' work parents and teachers' awareness of the relevance of parents' involvement. In this

specific case, the relationship between teachers and parents was also enriched and mediated by the presence of external actors (university researchers) directly involved in the experimentation activities.

Teachers, principals and other school personnel in suburban schools (see e.g. Italy, CS7, p. 180, CS8, p. 211) seemed to feel a responsibility to support what one might call social promotion of the local community and it seemed that the relationship with families is driven by this perspective. These actors attribute particular relevance to the involvement of families in supporting children in their learning experiences and consider school and family as two interacting parts of the same system (Italy, CS7, p. 185).

In a perspective in which school education – and science education in particular – is considered as a means of promoting social transformation (Italy, CS7, p. 178; Colombia, CS1, p. 119), teachers seemed to feel that they have to be strongly invested with the responsibility of their social function, able of mediating among different needs (ranging from the pedagogical to the political ones) and of actively participating to the life of their community.

Active involvement of the local community has been recognized as even more relevant in those contexts (e.g. Argentine, CS1, p. 28 et seq.; Colombia, CS1, p. 113) in which the local community's cultural identity is specific and distant (even linguistically in Argentine's CS1) from the one on which school teaching is based (Argentine teachers called it the "national culture").

In case studies carried out in schools based in indigenous communities in Latin American countries, it seemed particularly relevant to design and develop science teaching/learning experiences whose structure was compatible or otherwise interrelated with the cultural perspectives, the practices, the language of the local community. On one hand, it seemed important to recognize the way these communities consider people as an integral part of their environment. On the other hand, as long as these communities are not characterized by a strong differentiation of productive activities, insisting on the differentiation of areas of knowledge seemed to make little sense.

Case studies carried out in some Latin American countries (Argentine CS1, CS2, CS3; Colombia, CS1) highlighted that an effective integration of the school with the local community takes place when the school is able to interpret and account for the needs of the community. In some of these cases, science education activities were focused on addressing of local material needs such as the access to energy sources, the purification of water in order to make it drinkable, the protection of the environment, the development of a balanced diet. This approach to science education (Colombia, CS4, p.207) seems to make the teaching/learning experience particularly meaningful in that it addresses practical problems that are relevant to the community and while covering important science content it highlights its connection with the everyday life of the community.

Even in cases in which the material needs of the local community are less urgent, teachers emphasized the relevance of linking the way the educational experience is structured with the local socio-cultural context (see e.g. Italy, CS7, p. 181). These teachers highlighted that scientific disciplines – with their peculiar interrelation between

operative and explanatory aspects – offer a unique opportunity for personal development to those students who have scarce access to meaningful learning experiences due to their socio-cultural background.

As we emphasized as a preliminary remark to the TRACES research programme, research findings suggest that gender has a crucial role in determining different attitudes and learning styles and that science learning is a typical gender role–stereotyped domain in which boys and girls tend to be strongly conditioned by their self-perception with regards to scientific competences and skills.

TRACES' surveys addressed the problem with three specific questions included in the teacher questionnaire in all partner countries[3]. We asked teachers if they experience differences of interests in boys and girls towards different scientific themes or engagement in different types of activities.

A very evident result is that the issue is generally underestimated by the majority of teachers questioned. Most of respondents said that they do not notice difference among their male and female students and their comments suggest that taking difference into account is perceived as a kind of discrimination. The attitude perceived as "correct" seems to be treating all students as they were the same, the classroom as a whole, as if this would preserve equity.

Similar findings emerge from case studies. In Italy's CS1, CS6, CS7 and CS8 specific discussion groups were devoted to gender-related issues in science education. In all these cases, the topic of gender difference was the most controversial among all workgroup's discussions. There was an evident resistance to address the topic. When discussion did start, however, teachers had much to say about differences they notice between boys and girls.

RECOMMENDATION 7

Actors playing a relevant role in their community should be involved in a debate about the aims of science education. Societal and local community issues should be taken into account and inform science teaching.

Discussion about curricula, teaching methodologies, assessment strategies and more generally about priorities in science education, including its nature and social role, should be part of an enlarged and open debate involving teachers along with a number of other stakeholders. The debate should place particular emphasis on issues that are related to cultural specificities of local communities (e.g. different views of the world, perceptions of the relationship with the surrounding environment, organisations of material production).

A possible strategy to promote this debate is the construction at both the local and central level of consulting boards/commissions involving teachers, researchers,

[3] With the exception of Spain.

students' families, school principals and administrators, leading cultural actors in the local communities, people involved in the productive activities, educators, experts in humanities and arts.

Initiatives of this kind can also promote teachers' sense of being recognized and supported in their work and reduce the distance between general educational programmes designed by ministries and national boards of experts and actual teaching practice.

Schools can act as a special context in which relevant societal issue (e.g. waste management, conservation of the environment and pollution) are discussed with a number of different actors (e.g. teachers, citizens, professionals, scientists, administrators). Schools can be the space where the unique contribution coming from an educational perspective can fuel public debate in which not only students' families but also the broader community is involved.

At the local level, it would be specially relevant for teachers, students' families and the broader local community to share a common vision of school and (science) education. Schools should share with the local community the responsibility in pupils' learning process (*co-responsibility*).

Schools should see themselves as belonging to the community and promote this vision by taking the needs of the community into account and involving the community in its activities and decision making processes (*ownership*).

Schools should make it explicit that the knowledge taught in the classes is not disconnected from the students' and the community's everyday experience and culture and that this knowledge is usable, meaningful, relevant to the life of the community (*relevance*).

People from the local community can be involved in the planning of the school activities and invited in the classrooms to talk about science topics in terms of their experience and expertise. This also supports the connection between school learning and the local cultural traditions and with the local environments and its transformations.

Special educational activities should be organized to involve both students and parents. Particularly relevance can have the implementation of activities in which mixed groups of students from different grades, teachers and parents work together focussing on issues from their everyday life experience. End of course sessions can be organised, in which students present their parents about what they did during the course and their learning process.

Science and mathematics education activities should be structured in order to overcome the possible lack of significant stimuli that characterize students' everyday experience, providing students with opportunities to make sense of their experiences. Special emphasis should be given to operative explorations and problem solving with regards to fundamental science and mathematics concepts.

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