PhD dissertation
Compendium of published papers

Science Teachers' Professional Development in Contexts of Educational Innovation

Analysis of three initiatives

Author: **Digna Couso**
Supervisor: **Roser Pintó**

Departament de Didàctica de la Matemàtica i de les Ciències Experimentals

Bellaterra, January 2009

UAB
Universitat Autònoma de Barcelona

A mi madre, como siempre
a Javi, más que nunca
al color verde, ésta vez tiene que ser al color verde….

A mi padre, por haber luchado,
para que siga luchando

A todos los que quiero,
a todos los que me quieren

Presentació

Aquesta tesi doctoral esta estructurada seguint les directrius de la normativa per la presentació de tesis doctorals com a compendi de publicacions, que fou aprovada per la Comissió de Doctorat de la Universitat Autònoma de Barcelona a la sessió de 15 de novembre de 1994 i modificada posteriorment per la mateixa Comissió de Doctorat el 6/02/1997, el 19/11/2001 i el 6/02/2002.

L'article 68 d'aquesta normativa regula el format de la tesi doctoral per compendi de publicacions, de la següent forma:

> *Les tesis doctorals presentades com a compendi de publicacions hauran de contenir els apartats següents:*
>
> *a) Una introducció en la qual es presentin els treballs i es justifiqui la unitat temàtica de la tesi*
>
> *b) Un resum global dels resultats i la discussió d'aquest resultats*
>
> *c) Les conclusions finals*
>
> *d) Una còpia dels treballs ja publicats i admesos per la Comissió de Doctorat per a formar part de la tesi*

Seguint la normativa esmentada, hem estructurat aquest treball en 3 seccions principals:

- Secció 1: Introducció i justificació de la unitat temàtica del treball
- Secció 2: Publicacions presentades
- Secció 3: Resultats globals i conclusions

Per aquest treball, s'aporten tres articles originals que segueixen una mateixa línia d'investigació, l'estudi del desenvolupament professional dels professors de ciències en tres contextos diferents d'innovació educativa. Aquests tres articles han estat aprovats per la Subcomissió de Doctorat el dia 8 d'Octubre de 2008 (veure carta Annex 1) per ser presentats com tesi doctoral com a compendi de publicacions i s'adjunten en la llengua i format original de publicació.

1. Pintó, R., Couso, D., Gutiérrez, R. (2005) Using Research on Teachers' Transformations of Innovations to Inform Teacher Education. The Case of Energy Degradation. *Science Education*, 89 (1), pp. 38-55.

2. Couso, D., Pintó, R. (2007) Teachers' Collaborative Reflections about School-Based Science Innovation in Spain. A Lang, M., Couso, D., Elster, D., Mooney-Simmie, G., Klinger, U. & Szybek, P. (Eds) *Professional Development and School Improvement*. Cap. 3, pp. 75-118. Studienverlag: Viena (Àustria)

3. Couso, D., Pintó, R. (*acceptat, en premsa*) Análisis del Contenido del Discurso Cooperativo de los Profesores de Ciencias en Contextos de Innovación Didàctica. *Enseñanza de la Ciencias,* ICE-UAB: Barcelona.

La formació de la autora de la present memòria per optar al títol de tesis doctoral ha comptat amb els suport econòmic de les següent ajudes personals al investigador:

- Beca de **Formació del Personal Investigador** del Departament de Didàctica de la Matemàtica i les Ciencias Experimentals, Universitat Autònoma de Barcelona. Període 2000-2004.
- Beca per a estada pre-doctoral **Marie-Curie Training Site** al "Centre for the Studies in Science and Mathematics Education" (CSSME), School of Education, University of Leeds, Regne Unit. Curs 2004-2005.

Els treballs i publicacions que constitueixen aquesta memòria de tesi doctoral per compendi de publicacions han estat realitzats amb el suport de les següents ajudes a la investigació:

- **Projecte STTIS** (Science Teachers Training in an Information Society), finançat per la Comissió Europea. DG Research, dins del programa TSER. Ref: ERB-SOE2-CT97-2020. Any 1997-2000
- **Projecte EUDIST** (European Development of Innovative Science Teaching), finançat per la Comissió Europea. DG Education and Culture, dins del programa Sòcrates Comenius 2.1. Ref: 106278-CP-1-2002-1-DE-COMENIUS-C21. Any 2002-2005

Agraïments

Aquesta tesis no hauria estat possible sense les diferents contribucions de tanta gent que, afortunadament, m'ha acompanyat en aquest procés… En aquestes pàgines els hi vull agrair, de tot cor, tot allò que m'han donat i també el que m'han fet donar de mi mateixa, més del que m'hauria imaginat… Vull fer aquests agraïments a cadascú en la llengua en la que els hi diria en persona, perquè es així com ho sento i perquè donar les gracies és massa important per traduir-ho…

En primer lloc et dono les gràcies, Roser, per haver estat la meva directora durant aquests anys. Vas confiar en mi des del primer moment i m'has donat la oportunitat de treballar en projectes d'altíssim nivell, de cooperar internacionalment i d'embarcar-me en totes aquelles tasques que com a investigador també necessites saber, però que mai tens oportunitat d'aprendre. Gracies, sobretot, per ensenyar-me que és l'energia, i per desprendre'n sempre tanta que hom no pot mai aturar-se al teu costat.

En segon lloc, gràcies als autèntics protagonistes de les recerques que es presenten en aquest treball, els professors participants. Gràcies als professors del grup *Scientia Omnibus* (el Jordi, el Josep, la Josi, la Mapi, en Marcel, la Marta, el Ramon i la Sílvia) per acceptar-me en el grup, per continuar sent el meu grup, per mantenir-me arrelada a l'escola i per haver-me ensenyat tantíssim de la professió d'ensenyar. Sou el professorat entusiasta amb el que tothom voldria treballar. Gràcies també al Carles, a la Conxita, al Joan, la María Dolors, la María Teresa, la Viqui i de nou la Marta i la Mapi, per haver accedir a compartir, discutir i reflexionar plegats en el projecte EUDIST. Gràcies també a tot el professorat que va participar en el projecte STTIS, que va confiar en la nostre proposta didàctica i ens va obrir la porta de les seves aules. Gràcies a tots per haver-vos "embolicat" en aquestes aventures i per continuar tant oberts a participar en les noves ...

I also want to thank the international researchers who participated in these two European projects, STTIS and EUDIST, for the wonderful opportunity it has been to work with them all. I can only say that I have learnt enormously from these experiences, both from our agreements and disagreements, and I wish I will continue having the opportunity to work with them in the future.

Being this work a compendium of research papers, all co-authors, reviewers and editors that participated in these publications have had an enormous contribution. Tengo que dar las gracias especialmente a Rufina, coautora de la Publicación 1, por ser una profesora e investigadora excelente, por su contribución siempre interesante y sagaz y, sobretodo, por ser una gran amiga con la que ha sido un placer trabajar. I also want to thank Manfred for his excellent editorial work of Publication 2 and to J. Olson for the productive comments received. Finally, thanks to the reviewers of Publications 1 and 3, which would have been very different without their critical comments and suggestions..

In addition to the researchers directly involved in the research projects included in this thesis, other international and national researchers have been a great personal and professional influence to me. I want to thank specially Costas, Denise, Paul and Sibel, who in different times and at different moments, have help me a lot with their professional advice and friendship. En España, quiero agradecer a Marilar las puertas que siempre me ha abierto.

Most of the literature review that forms part of this work was done in the University of Leeds, during my stay at CSSME. I want to thank all the people there for their friendliness and readiness to help. In particular, I want to thank John and Hillary for the interesting professional exchange I enjoyed under their supervision. I also want to thank specially Jacqueline, who was a wonderful host at the time and continues being a close friend, She has also helped me in the proofreading of parts of this work.

El camí que m'ha portat fins a aquest treball no hauria estat la meitat de ric sense el intercanvi amb els molts estudiants de doctorat amb els que he tingut la oportunitat de compartir angoixes, alegries, estones de frustració però també les estones més divertides que he passat els darrers anys i que sempre formaran part del meu anecdotari… Des de los tiempos (¡parecen inmemoriales!) del despacho 128, gracias a Adriana, Agustín, Álvaro, Andrés, Bea, Cristian, Edel, Fanny, María Luisa y Rita, y todos los que cariñosamente me llaman "la Galle", por todo lo que me habéis dado, por lo mucho que me habéis enseñando de vuestros corazones y países, y porque seguís siendo mis compañeros del alma, aunque algunos estéis tan lejos… Gracies també als companys d'aquí i de sempre, a la Marta de Girona, i sobretot a l'Anna i el Jaume, amb els que he compartit molt més que feina i estudis, i que per mi ja són part de la meva família més propera. Thanks, too, to the international Marie Curie and PhD students at

Leeds: Cristine, Gultekein, José, María Ines and her twins, Morifuji, Noah, Paola, Teresa and Sonja, especially for the biology-lab international film sessions late at night after an exhausting work day, and for adopting me for a year in their multicultural family. Gracias a Rut, presidenta del club “Leedeño”, por su fe inagotable en mí y porque desde que la conozco puedo decir que tengo una hermana en el sur.

Durant tot aquest temps he tingut la sort de sempre poder fer una de les coses que més m’agraden: ensenyar (i aprendre ensenyant) ciències a l’escola i a la universitat. Vull donar les gràcies a tots els meus companys i al equip directiu de l’Escola Frederic Mistral - Tècnic Eulàlia, per creure en mi i ajudar-me a complir el meu gran somni, que era ser professora de ciències. Gràcies també a tots els professors i professores del Dept. de Didàctica de les Matemàtiques i les Ciències Experimentals de la UAB, per confiar en mi i encarregar-me taques de docència i coordinació. Gràcies, sobretot, a aquells amb els que he compartit assignatures a magisteri (Joan B., Joan F. i Josep, allà on estiguis) per compartir tot el vostre *saber fer* docent amb mi, i a les companyes i grans mestres meves del Màster de Formació del Professorat de Secundària Conxita i Montse R., sense les quals no hauria pogut fer-ho. Hi aprenc cada dia, de vosaltres. Gràcies, sobretot, a tots els alumnes que he tingut durant tots aquests anys, per que sou la raó de ser de tot això...

Durant aquests anys també he tingut la sort de desenvolupar la meva segona passió, la recerca en didàctica, en el CRECIM. Vull agrair molt especialment a les meves companyes d’allà les bones estones de complicitat i companyia, la seva paciència en els darrers temps per tal que jo pogués acabar aquest treball, i els ànims que m’han donat per seguir... Moltes gràcies a l’Elena, l’Eva, a Luísa, la Marcel·la, la Marisa, la Montse i sobretot la Sílvia, que sempre ens recorda que hem de deixar entrar el sol per les finestres quan estem capficades en el nostre món... Vull agrair també a molts altres que hi han treballat o col·laborat en el passat i als que continuen fent-ho, però que són tants que no puc citar-los un a un.

Abans de professora, però, he tingut la sort de ser (i espero continuar sent-ho!!) alumne de les millors mestres. En els cursos de doctorat del departament vaig endinsar-me en l’epistemologia amb la Mercè; vaig comprendre el poder de l’avaluació amb la Neus i vaig enamorar-me de la metodologia i la recerca amb la Mariona. La poca biologia que sé la dec a la Pilar. La física me la va tornar a ensenyar la Roser. A la química, que mai m’havia agradat, li veig el què gracies a la Mercè i la Neus. La geologia, gran desconeguda per mi, ja no ho és tant gracies al Joan B. i la Conxita.

A banda dels professors i investigadors, al Departament i a la Facultat d'Educació sempre m'han ajudat moltes altres persones, altres companys de feina. Vull donar-los-hi les gràcies a tots, començant per la Bego i el Benja, que s'encarreguen de que tot vagi bé fent que sembli d'allò més fàcil; als laborants Manolo i Jose, i al Miquel de manteniment, que saben fer allò que ja ningú sap fer i que sempre es prenen com un repte propi quan els demano un muntatge "más difícil todavía"; a la gent de consergeria, secretaria i administració; a les noies de copisteria que aquests dies tinc boges; a les del servei de neteja, que em donen els primers "bon dies" de la jornada de bon matí. I als companys del bar de la Facultat, pels milers de cafès amb llet *en got llarg,* com a casa, sempre acompanyats d'un somriure.

Por último, quiero agradecer a los míos...

... a mis amig@s de Mollet, de casa, la Mari, la Sílvia, la Susana; a Alberto y Alex, y a la pequeña Ariadna, por no dejar que la tesis nos haya separado a pesar de que casi nunca puedo verles. ¡Os vais a cansar de mí a partir de ahora!

... al Miquel i al Pepe, els meus millors amics de la carrera, per acabar abans que jo i posar-me pressió. Per fer-me riure tant! A la Neus, la meva còmplice, per treure'm tota la pressió a base de bones estones.

... a mi segunda familia, la familia de Javi, especialmente nuestros cinco sobrinos, por echarme tanto de menos cuando no he podido ir porque estaba "haciendo tesis".

A mi familia …

... a mi madre, *a miña mamaíña*, por haberme enseñado lo más importante en la vida: que la honestidad es el único camino. Por su amor incondicional. Por ser el modelo que quiero seguir. Por que con ella nunca estoy sola. Por sonreír en los días grises. Por tejer con sus manos una red de sostén de la que no puedo caerme.

... o meu pai, porque sé que cada día es para él una lucha, y que lucha también por nosotros.

… a mi hermano, mi primer amor, mi primer admirador, por que no necesitamos hablar para comunicarnos, porque todavía me hace reír como una niña.

Y por encima de todo,

… a Javi, por acompañarme en la vida como una segunda piel, tan noble, tan cómoda, tan mía, que ya no podría vivir sin ella. Por haberme enseñado que puedo querer tanto y por quererme tanto. Por que aprendo de él cada día. Por que en sus ojos sinceros no me importaría ahogarme para siempre.

La dernière chose qu'on trouve en laissant un ouvrage
est de savoir celle qu'il faut mettre la première.

Blaise Pascal
Discours sur les passions de l'amour

(The last thing one settles in writing a book
is what one should put in first)

Abstract

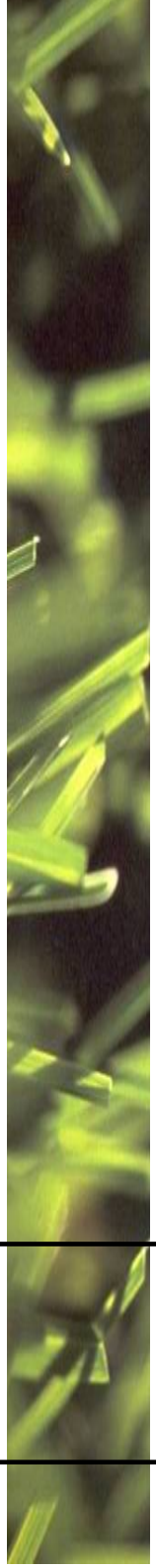
This research examines the relationship between educational innovation and professional development in Science Education, arguing that when teachers play an active role in innovation these scenarios become professional development scenarios themselves.

From a literature analysis of the field, characteristics of effective professional development are found according to a situated and socio-constructivist view of teacher learning. From this analysis, a model of ongoing and systemic professional development within a *new* school and professional culture is developed. This model stresses the importance of a focus on the subject, participation in authentic cooperation, and an inquiry/reflective stance from teachers sharing the common goal of fostering students', but also their own, learning.

The empirical part of this thesis includes the published reports of three different pieces of research undertaken in a variety of scenarios of implementation of innovations in science education in Catalonia. These contexts cover a rich spectrum: from top-down, short-term and research-based teacher training proposals to bottom-up, on-going, curriculum development initiatives. Both the shortcomings and positive outcomes of these scenarios are analysed concerning what professional development process teachers experience within them, reinforcing the aforementioned theoretical model with empirical evidence. Methodologically, the research uses different techniques for the analysis of language data, which are both Qualitative and Quantitative Content Analysis and Discourse Analysis. Data come from a variety of sources: video-tapes of lessons, video and audio tapes of teachers' meetings, teachers' semi-structured interviews, open questionnaires and teachers' curriculum documents. Some instruments for Quantitative Content Analysis are developed.

The implications of the research work are twofold. A *new* model of professional development in which this process is intertwined with school-based reform and innovation in which teachers play an active role is proposed. In addition, the research offers some methodological tools regarding the analysis of teachers' cooperative discourse.

Table of contents



SECTION 1. Introduction

Justification for the Research

Research Purpose

Thematic Unity of the Research

Justification for the research

The compendium of published papers that form this dissertation explores different aspects of the professional development of science teachers in a variety of contexts of educational innovation. The analysed scenarios have been purposefully chosen as examples of different participatory models of teachers in educational change. To which extent and how this variety of scenarios can foster the professional development of the science teachers involved is the focus of the research project.

The justification for this research requires addressing the following:

- The importance of teacher professional development in science education.
- The interest in linking professional development and educational innovation.
- The relevance of the particular contexts of educational innovation included in this study.

In the following sections, each of these aspects will be analysed with the intention of making clear the significance of this research for science education.

1. Why teacher professional development?

> "[...] to consult the more recent handbooks, publication series, monographs, and research journals is to witness an explosion of interest in the teaching career from virtually every epistemological and methodological quarter. Why the explosion of interest? Why now? One reason appears to be the growing recognition that teachers' commitment, energy, knowledge, and skill may be the central determinants of schools' effectiveness" (p.11)
>
> M. Huberman, C. L. Thompson and S. Weiland (1997)
> Perspectives on the teaching career
> *International Handbook of Teachers and Teaching*

Research in education during the last decades has experienced, as stated by Huberman and colleagues, an *explosion of interest* towards teachers and teaching (Huberman, Thompson and Weiland 1997). The Science Education field has not been an exception. Ten years ago, the analysis of the state of the art of Science Education research in the *International Handbook of Science Education* evidenced that research about science teachers' education has acquired, since the 80's, relevance as a particular domain (Munby and Russell 1998). The appearance in the 1990 of the first *Handbook of Research in Teacher Education* (Cochran-Smith, Feiman-Nemser, McIntyre and Demers 1999); in 1997 of the first *International Handbook of Research on Teachers and Teaching* (Biddle, Godd and Goodson 1997) with a second volume available soon (Saha and Dworkin 2009); and also the recent publication of a *Handbook of Teacher Education* (Townsend and Bates 2007), evidence that the academic interest in the field continues its expansion.

The reason behind this interest in science teachers and their education is also mentioned in the quote of Huberman *et al* (1997): the growing recognition that teachers', their knowledge, beliefs, values and competence, have a crucial impact on school effectiveness. This recognition has its roots in the theoretical frameworks of teacher thinking (Clark and Peterson 1986; Calderhead 1987; Marcelo 1987). Research on teacher thinking has allowed a paradigm shift from a behaviourist conception of teachers towards that of a cognitive professional, whose thoughts influence her activity. This apparently *simple* idea has, however, been the source of large amounts of research focused on teachers' knowledge (what is it that teachers' know and need to know to teach) and on the process of teachers' learning and change

(how this knowledge is acquired by teachers and used in their professional practice). It has been within this paradigm that different notions of teacher knowledge (subject matter knowledge; pedagogical content knowledge; tacit, craft and/or practical knowledge) but also beliefs and values; the view of the teacher as a reflective practitioner (*in*, *on* or *about* practice) or the idea of teachers' conceptions and need for didactical change, among other crucial concepts in Science Education, have been proposed and researched. Results of different studies within this paradigm have shown that the level of professional development of teachers, in other words, what teachers know, can and want to do, has a strong influence on their teaching, and thus on what their students learn.

The idea that teachers' development is a crucial factor for the success of education has been informing educational policy since the 90's and is still today a central argument in most policy recommendations. In the US, the stated idea that *"what teachers know and can do is the most important influence on what students learn*" (p.6) was the basic premise of the influential report *What matters most: teaching for America's Future* (NCTAF 1996). This statement was the result not only of educational research's influence but also of global educational policy analysis showing that investments in teachers' knowledge and skills net greater increases in students' achievement than any other uses of the educational budget. According to Darling-Hammond (1999), after this policy report *"For the first time in the better part of a century, the United States is now focusing on the quality of teaching as a key element in the improvement of education [instead of] assuming that curriculum packages, testing programs, and management schemes will change schools"* (p.31). Almost fifteen years later the also well-known OECD report *Teachers' Matter: Attracting, Developing and Retaining Effective Teachers Education and Training Policy* re-introduces this idea in the present worldwide educational scenario, stating that of those variables which are potentially open to policy influence, factors related to teacher quality are the most important influences on student learning (OECD 2005), and should be addressed accordingly.

From all the above, the interest in the professional development of teachers appears unquestionable. Research on teacher professional development is not only a contribution to a rich, productive and growing research field, but also to an educational political priority if improvement of students' results aims to be achieved. In this sense, we consider that the focus of this study in this particular topic is relevant in the present educational context. Of major interest, however, is the issue of how to promote the

desired professional development of teachers. What is known about this topic will be discussed within the following introductory sections and also in the papers that form this compendium. The particular research studies included here also expect to contribute to the present knowledge of the topic with their own empirical findings.

2. Why professional development in contexts of science curriculum innovation?

> "For something as obvious as the need to relate teacher development and educational change, it is surprising how little systematic attention has been devoted to understanding the topic and taking the appropriate action. In fact, the focus on the link between teacher development and educational change is barely fifteen years old." (p.1)
>
> M. Fullan and A. Hargreaves (1992)
> *Teacher development and Educational Change*

> "We have perspectives from reforms past and present, but one lesson stands out- the reforms that had the most impact affected three areas: they changed the curriculum, they improved teaching, and they provided professional development for teachers." (p.21)
>
> R. W. Bybee (2006)
> The Science Curriculum: Trends and Issues
> *Teaching Science in the 21st Century*

The interest in teachers and teacher professional development is closely related with an interest in educational change and a subsequent reform movement worldwide. This is because educational change is generally driven by dissatisfaction with students' results and motivation, which, as discussed previously, is related with teachers' classroom practice and thus with teachers' knowledge, beliefs and values. Whatever the extend of change, either a broad educational reform or a small curricular innovation, teachers are the ones who have to bring it to practice and need to be professionally developed to do so. In this sense, teachers are the most influential factor in educational change (Duffee and Aikenhead 1992), and educational change becomes actually a matter of teachers' development (Fullan and Hargreaves 1992).

In Science Education, in particular at the secondary school level, there is common agreement that change is needed. Different indicators are available. There is an evidenced decrease in the number of students interested in science and technology studies in many countries, particularly female students regarding physical sciences (OECD 2006). There is also worrying results about attitude towards science from secondary-school students, particularly in developed countries, as findings from the ROSE project point out (Schreiner and Sjøberg 2004; 2007). Our particular context,

Catalonia, has shown not to be an exception here: an abrupt decrease of interest from primary to secondary school students has been identified (Marbà 2008). In addition, there is a public general dissatisfaction regarding actual results focusing on students' scientific literacy and competence coming from the well-known PISA international study (OECD 2001; 2004; 2007) and other national assessment initiatives. Never before of this international accountability scenario there has been more data in education supporting an almost global need for reform. Despite the unquestionable importance of all these results, they have evidenced nothing that science education researchers had not pointed out earlier: that science education in its traditional form has become *outmoded*. The traditional way science education is generally taught does not adequately prepare future citizens, less even engage them, to understand and face science and technology issues in the present rapidly evolving society (Millar and Osborne 1998).

Due to this dissatisfaction with traditional science teaching, in many nations around the globe science education has been going through a process of curriculum change over the last decades. Despite enormous differences of context, these international reform efforts share some common characteristics across countries (Black and Atkin 1996; Bybee 2006). They share new perceptions of the nature of science together with a new appreciation of the social relevance of science. Authors speak of a new *epoch* in Science Education history, referred to as the standard-based and accountability era of the *No Child Left Behind* Act (Bybee 2006) or the *Scientific Literacy* movement (Roberts 2007). For Fensham (2007), *Science for All* emerged in the 1980s as the slogan that signalled the recognition (in UNESCO and many nations worldwide) that school science needed to be reconceptualised according to the new educational aims. Within the science classroom, this implied a quite global change from *"lectures to convey science content and technical training for acquiring practical skills [while presenting science] as a rigid body of facts, theories, and rules to be memorized and practiced"* (p.138), towards the teaching for scientific literacy, the introduction of reflection on science and the engagement of students in active inquiry, among others (van Driel, Beijaard and Verloop 2001). The particular context of this study is not an exception. The Spanish government has very recently launched a new educational law, LOE[1], which is the second important reform attempt since the very influential LOGSE[2]

[1] LOE stands for "Organic Law of Education". The official reference *is "Ley Orgánica 2/2006, de 3 de mayo, de Educación. BOE nº 106 de 4 de mayo de 2006"*

general law in the 90's. LOGSE was referred to as a strong opportunity for change regarding the new *Science for all* curriculum (Jimenez-Aleixandre and Sanmartí 1995), but also a very demanding reform initiative (Black and Atkin 1996) which has been discussed to have been adopted only superficially, more in rhetoric than in effective practice (Pro Bueno 2006; 2007), mostly due to lack of enough teacher participation (Coll and Porlán 1998). The implementation in Catalonia of the new legal educational framework, which is standard-based around the notion of scientific competence, has just begun in schools. The new science curriculum is being implemented since the school year 2007-08 using a model for reform implementation quite similar to the one before. Within these broad reform agendas, continuous smaller-scale curriculum innovations are also taking place, either driven by the official reform attempts or research-based inspired within the Science Education field. The innovations presented in the three publications that form part of this compendium are an example of small scale initiatives aiming to change the way science is taught in the classroom within this broad reform efforts.

Despite the extensive call for instructional reform in the science classroom of the last two decades, change has not been extensive (Davis 2003). Analysis of the impact of these global reforms and also of smaller curricular innovations shows unsatisfactory results. Science education researchers have largely discussed this issue, acknowledging that reforms pose great, in fact sometimes unexpectedly great challenges to teachers (Jimenez-Aleixandre and Sanmartí 1995; Black and Atkin 1996; Darling-Hammond 1997; Furió, Vilches, Guisasola and Romo 2001; Pintó 2005). As Davis (2003) points out, what science teachers involved in innovation are telling us is that *change is hard.*

According to the mentioned difficulty, innovation is generally closely connected with in-service teacher education and continuous professional development initiatives, which try to support this process. This is not new. Ever since the birth of the science curricular reform movement in the late 1950's *"a large portion of science teacher education has been connected in some way to attempts to introduce curricular change"* (p.36, Anderson and Mitchener 1994). However, if reforms are not having the expected results, this implies that the traditional teacher education or continuous professional

[2] LOGSE stands for "Organic Law for the Ordering of the General Educational System". The official reference is *"Ley Orgánica 1/1990, de 3 de octubre, de Ordenación General del Sistema Educativo. BOE nº 238 de 4 de octubre de 1990"*

development initiatives are also not having the expected impact. Or, in other words, they are not adequately supporting the process of professional development that teachers need in the reform scenarios. Taking on the role of a self-critic, one could say that teaching science in the new, "*reformed"* way (for scientific literacy, according to standards, for the achievement of scientific competence, …) has shown as hard for the teachers as the teacher education for this new teaching is showing hard for teacher trainers and educational researchers.

Little (1993) expresses the shortcomings of traditional teacher education within reform scenarios as a problem of "fit" between *"the ambitious visions of teaching and schooling embedded in present reform"* and the *"prevailing configurations of teachers' professional development [initiatives]"* (p.129). The author argues that the dominant model of teachers' professional development is a *training* model, focused primarily on *"expanding the individual repertoire of well-defined and skilful classroom practice"* (p.129), which can not meet complex demands in complex contexts of teaching and reform. Other authors have also criticised that, despite the global recognition of the importance of teacher continuous professional development, the characteristics of the initiatives available to teachers are inadequate for the requirements of reform. They have been described as fragmented, intellectually superficial, and, more importantly, as neglecting what it is known about how teachers' learn (Putnam and Borko 1997; Ball and Cohen 1999; Borko 2004). These sorts of professional development opportunities, isolated in time, space and goal from the actual practice of teachers, can not be the source of systemic, less even school-based change.

As a result, a *new* conception of teacher professional development strongly linked with the process of innovation has been proposed. Fullan and Hargreaves (1992) suggest that teacher development opportunities should be innovation-related and continuous during the course of implementation, including both formal and *informal* activities. What the authors refer to is that, within this view, professional development opportunities are related to, but differentiated from, traditional teacher education initiatives. The reason behind this notion is that, fortunately, professional development does not only happen across the formally planned, generally out-of-school, teacher education settings. The literature in this area shows that much professional development can be found in activities as diverse as the professional discussion with colleagues; the systematic inquiry within an action-research group or the personal reflection on practice. Not surprisingly, these sorts of scenarios and activities are quite often an explicit part of the *new*, *innovative,* reform and innovation scenarios.

All of the above stresses the idea of an interesting *bidirectional* relationship between the new conceptions of professional development and innovation. On the one hand, professionally developed teachers are necessary for innovation to succeed, which make new and well designed professional development opportunities necessary to support innovation. But on the other, adequately designed innovation, such as innovation where teachers play an active role, can in turn be a good context for teachers' professional development. This is because by questioning and trying to change their practice, that is, by actively participating in innovation and being adequately supported to do so, teachers can develop and learn. In this sense, there is a strong feedback relationship between both processes which, as Fullan's quote expresses at the beginning of this section, deserves more systematic attention. It is within this emerging conception of *new* views of professional development and innovation that sees them as closely related, that the central question guiding this research work makes sense: *how do teachers professionally develop within different innovation contexts*.

3. Why three different scenarios of innovation?

> "One message of this book is that things are much more complicated than they seem. The book is drawn from a number of case studies and the overwhelming impression from the evidence is of diversity […] they also illustrate the complexity of change. Fashionable opposites, such as top-down v. bottom-up, or teacher-active v. teacher-passive, are not helpful. In the real world action and change take place in more complex ways and at intermediate points along these bi-polar axes". (p.1)
>
> P. Black and J.M. Atkin (1996)
> *Changing the subject. Innovations in Science, Mathematics and Technology education*.

Educational innovation and reform can take place in very different sorts of scenarios, according to the reform agenda. The relationship between the characteristics of these scenarios and the efficiency of the innovation process has been largely researched. In Science Education, the pioneering work of Black and Atkin (1996) analysed different reform processes showing that there is much more success when teachers' play an active role in all the phases of curriculum reform, from planning and designing to implementation and assessment. Teachers' involvement in all phases of reform was not merely evidenced as important in ethical and emotional terms, despite it was clear that teachers' personal involvement and commitment with the reform could not be neglected. The major interest for the participation of teachers in the innovation was related with ensuring that teachers *were able to* implement it. Or, from a different viewpoint, that the innovation is actually able to be implemented in practice.

As has been discussed in previous sections, educational change depend on what teachers do and think (Fullan 2001), on their attitude towards change but also on their knowledge and beliefs (van Driel, Beijaard et al. 2001). When these knowledge and beliefs are too distant from what the innovation demands, or even act as obstacles to it, problems arise. If teachers do not fully understand and share the content and rationale of the innovation (subject matter knowledge, pedagogical content knowledge, general *didactics*[3]) and master the technicalities involved, it is quite likely that teachers might

[3] In this work, we use quite often the word "didactics" and other versions of it following the continental tradition of Science Education, which refers to this field as Didactics of Science and to the general knowledge about teaching as "Didactics" in addition to Pedagogy. Despite we know that the root "didactic"

make critical transformations when implementing the innovation in practice (Pintó 2005). These transformations are not the normal adaptations of the innovation to the teachers' style and classroom or school context, but didactically critical ones that can inhibit the achievement of the goals of the innovation.

We had the opportunity to explore these transformations in detail in the international project STTIS[4] (Pintó, Gutiérrez, Ametller, Andresen, Balzano, Boohan, Chauvet, Colin, Couso, Giberti, Hirn, Kolsto, Monroy, Ogborn, Quale, Rebmann, Sassi, Stylianidou, Testa and Viennot 2001), which is the context of the first publication included in this work (See Publication 1, Pintó, Couso and Gutiérrez 2005). Within STTIS, teachers' transformations of certain innovations in the physics curriculum were analysed. The participation of teachers in this project followed a traditional pattern: science education researchers designed research-based innovations and shared their rationale, content and materials with small groups of teachers in also traditional teacher education settings: short-term, out-of-school, top-down and content-centred. Results showed that teachers across Europe, even those highly motivated by the reform, implemented the new curriculum without taking into account most *critical details* according to the rationale of the innovation (Viennot, Chauvet, Colin and Rebmann 2005), distorting in this sense the didactical meaning of the new curriculum. Ogborn (2002) discussed this issue when advocating the need of teachers to have *ownership* of the innovation, both in emotional terms but also regarding the mastering of the knowledge involved. According to the author, this ownership can only be achieved if the teacher takes part in the innovation process from a very early stage.

The general results of the STTIS project are interesting for the research community in the sense that they offer a very detailed account of the particular transformations that teachers make when facing traditional innovations, suggesting also detailed ways of addressing these particular and crucial problems through teacher education. The particular study included in this dissertation does so regarding the energy concept, most particularly the idea of energy degradation, for secondary school teachers (Pintó and Gómez 1999; Pintó, Gutiérrez and Couso 2001). In this sense, STTIS was realistic

---

has a meaning more related to instruction than to education and thus the burden of strong methodological and technical connotations in the Anglo-Saxon tradition, we agree with Adúriz-Bravo *et al.* (Adúriz-Bravo, Aisenstein, Bianchini, López-Arriazu, Simón and Valli 2003) that in continental Europe and Latin America this word can better convey the idea of specific academic studies and a research field.

[4] *Science Teacher Training in an Information Society*. Project funded by the EU, DG Research, under the TSER programme. Ref: S&S-16-042942. Reports available at the URL http:// crecim.uab.cat/websttis

and followed the *normal* way innovation is generally introduced in the classroom across the different European contexts. However, STTIS was critical with this approach to innovation and reform (Pintó 2005). From STTIS it was clearly evidenced in a science education context and regarding innovations with a strong focus on subject-matter, what had already been discussed in reviews of general education reform: that attempts to change education by top-down initiatives which just flood the system with new ideas "*fall flat*" (Fullan 2001).

Top-down approaches have been largely discussed and criticised in education (Tobin and Dawson 1992). Within these contexts, reforms have shown to be adopted only on the surface, producing minimum classroom change. Behind this approach to educational change, there is a simplistic, technological, *input-output* view of the process. The focus is on *delivering* educational ideas and materials to schools, considering that a very well designed "input" to the educational system will produce automatically the desired "output". And will do so for everyone, everywhere. In top-down reform it is expected that universal didactical knowledge "built-in" to the teaching and learning materials or reform policy documents would be understood and used within the system (by its participants) in an straightforward manner. Surprisingly, the didactical model behind this way of organising educational reform is a purely *transmissive* one, despite generally *constructivist* teaching being what the reform initiatives usually suggest to teachers as the more effective approach for their classrooms. We have already discussed that teachers would neither desire nor be able to implement this sort of innovations in an appropriate way. However, failure of implementation in top-down reform approaches is not only due to neglecting the teachers' role, but also by neglecting the students, the school and in general the context and culture in which the new curriculum is to be embedded (Wallace and Louden 1992).

As an alternative, more bottom-up reform initiatives have been proposed. These approaches are varied, but have in common the placing of schools and teachers at the core of the reform process. Behind the notion of bottom-up reform is the inclusive idea of systemic reform, that is, reform that takes into account all the components of the educational system so that they all "pull together" for reform to happen (Olson 2002). In this sense, bottom-up reform initiatives advocate teachers to play a more active role in innovation, relying on notions such as the "teacher as designer" (Calgren 1999), "curriculum maker" (Clandinin and Connelly 1992) or "researcher" (Elliott 1991). This active involvement of teachers makes bottom-up reform scenarios interesting for

bridging the well-know research to practice gap, doing so in such a way that contextualisation or adaptation of the innovation to the real context can take place and avoiding the counter productive *"press for uniformity*" of top-down approaches (Olson 2002). The bottom-up reform approach also advocate schools to be the centre of reform, in the sense that the previous roles are expected to be played by teachers at the school (within the school), among schools or with a clear school/classroom emphasis. This resonates with ideas of school-based curriculum innovation and school inquiry, both related with Hargreaves' (1999) notion of schools as "*knowledge creating institutions*"[5]. How teachers become curriculum makers or how schools use and generate useful educational knowledge is, of course, the central foci of research on these approaches.

In his review of educational change, Fullan (2001) found, together with *"virtually every research study in the topic",* that collegiality and interaction are crucial points to educational change. Results show that at the teacher level, *"the degree of change is strongly related to the extend to which teachers interact with each other and others providing technical help*" (emphasis in the original). Regarding schools, *"collegiality among teachers, as measured by the frequency of communication, mutual support, help and so forth, was a strong indicator of implementation success"* (p.124). In this sense, bottom-up reform relies on cooperation as a crucial aspect. However, not all forms of cooperation are equally useful for innovation. Collegiality and interaction among teachers has to be *purposeful* towards the achievement of change, have enough status and recognition, and occur with enough regularity and quality, in the sense of becoming a new *collaborative working culture* (Fullan and Hargreaves 1992) in the school and among teachers. We agree with Seashore and colleagues (2003) cited in Bolam, McMahon *et al.* (2005), that "*our interest is not only in discrete acts of teacher sharing, but in the establishment of a school-wide culture that makes collaboration expected, inclusive, genuine, ongoing, and focused on critically examining practice to improve student outcomes"* (p.3). Other authors have referred to this change of culture in the way teachers work together and with others relying on the well-know notion of *community* (Lave 1996; Wenger 1998), this has given rise to the ideas of communities of practice, of professionals and of learners which will be further

[5] One of the important discussions within this bottom-up approach is whether local knowledge generated at school level it is not only "local" knowledge (knowledge useful for the school in the school context), but also knowledge which can have a public or general interest (Cochran-Smith and Lytle 1999). This aspect will be deeper explored in following sections.

discussed in following sections of this work. In this sense, the third paper that forms part of this thesis (See Publication 3, Couso and Pintó *in press*) analyses some aspects of the cooperative work of science teachers for curriculum innovation in a particular bottom-up scenario, in which teachers and teacher leaders work autonomously in a way that shares the characteristics of an emerging *professional learning community*. Despite the research done does not analyse in detail all aspects involved in teachers' cooperation, it offers an account of some characteristics of these particular bottom-up cooperative contexts and their possible influences on the professional development of the participating teachers (Couso 2002a).

From the description of the context of Publication 3 it could be inferred that we hold a naïve view of bottom-up reform, associating this approach only with initiatives originated by teachers, in which teachers participate in educational change by themselves, in isolation from other educational authorities and experts. However, this is not the case. Autonomous and self-organised teacher groups participating in curriculum innovation, as the one analysed in Publication 3, are quite exceptional. Despite the interest of such contexts when researching teacher cooperation in curriculum innovation, these scenarios are neither easily promoted nor scalable. Because success in these contexts is dependant on teachers already having enough educational expertise and motivation, they have a small potential impact for global educational change. On the other hand, they allow little external guidance on the direction of change accomplished within these initiatives, or on the sort of professional development achieved by them. In this sense, they can not be the typical example of bottom-up reform, but an extreme case. In general, curriculum innovation or reform initiatives that have a bottom-up orientation are organised within *school-university partnerships*. These partnerships serve different purposes. On the one hand, teachers can receive the necessary support to engage actively in innovation. On the other, within these partnerships, teachers, researchers and educational authorities' agendas can be shared and taken into account. This is important for two reasons. First, because the new working cultures that bottom up reform demands need skilful guiding, facilitation and support from teacher leaders, teacher educators or educational researchers, as they have shown to be quite challenging scenarios for the traditional teacher and the traditional school (also for the traditional teacher leader, educator and researcher). Second, because bottom-up reform is proposed as a more effective way of achieving educational change, a change that can not (as has been discussed) neglect teachers' views, but which can not also neglect research results and educational policy. As a consequence, curriculum innovation or reform initiatives that

follow the bottom-up approach are generally either originated, promoted or both within the educational research field. Being an innovative approach to educational change, quite often researchers complain that they find themselves having to *create* the bottom-up reform scenarios they want to research (Wilson and Berne 1999).

Another important aspect of bottom-up reform that has been mentioned but needs further clarification in order to explore this approach is where its *locus* is. This refers to the fact that *bottom-up* is used in the literature to refer to initiatives which could be described as mostly "*teachers*-up" or, more interestingly, "*schools*-up". Despite both views being strongly related (in fact, Hargreaves (1994b) discusses that there is a *synthetic* relationship between professional and institutional development), the initiatives that are focused on one or the other are quite different, depending strongly on organisational aspects within the educational system. In the following paragraphs, these two possible conceptions of the approach will be further discussed, showing that while the former is easier in the Spanish/Catalan context due to singularities of the school organisation, the latter is more desirable and pursued, despite contextual difficulties.

In the international literature, which is mostly Anglo-Saxon, bottom-up reform is strongly associated with school-based reform originated and supported within the school hierarchical system that characterises these contexts. In this sense, this literature discusses how the new collaborative and innovative culture necessary for bottom-up reform is difficult to develop in a school without the active support of leadership, both in terms of headteacher or principal commitment and shared or distributive leadership (Mulford and Silins 2003). As McLaughlin and Talbert (2001) describe, the role of principals in these strongly hierarchical school contexts is crucial, because *"for better or worse, principals set conditions for teacher community by the ways in which they manage school resources, relate to teachers and students, support or inhibit social interaction and leadership in the faculty, respond to the broader policy context, and bring resources into the school"* (p.98). Apart from the roles of principals and headmasters, internationally leadership also refers to other "designated teacher roles", generally according to institutional agendas, which are more related to *division of managerial labour* than to authentic teacher leadership (Little 2003).

This situation, however, is very different in the Spanish and Catalan educational system[6] in which this study is conducted. In the average Catalan school[7], hierarchy does not generally play an important role in terms of leadership. One can speak of a *de facto* merely bureaucratic hierarchic system rather than a hierarchy linked to professional leadership (Escudero 2004). This has been studied in the Spanish literature about school organisation as the *principalship problem*: the difficulty of combining requirements of professionalism for the principal role with the fact that, according to legislation, principals are teachers of the school, democratically elected by the school community (representatives of teachers, students and parents), who after a period as headteachers return to *normal* teaching. Despite some benefits of this "participatory model", there are also important shortcomings. Principals and heads of department in the Catalan school are teachers with different organisational and bureaucratic responsibilities, rather than school managers and educational leaders purposefully chosen[8].

This particularity of the Spanish-Catalan school organisation is crucial when defining the *locus* of bottom-up reform and how it can be promoted in this context. In Spain and Catalonia, school-based reform is *a priori* more difficult than in other educational contexts, because the decision to participate in curriculum innovation is taken mostly at the personal teacher level rather than at the school one. Principals and headteachers do not necessarily have enough status and definitely not enough power to involve a complete school or department in innovation or promote a more cooperative school culture[9]. However, as mentioned before, the school is the desired locus of bottom-up

[6] Spain and Portugal are discussed to share a singular (and unique) type of school principalship within the European Union (Barroso 2002)

[7] We refer here to state schools, that is, schools owned by the state, which are the majority of schools in the Spanish and Catalan educational system. In semi-private and private schools, the school organisation is different and leadership related to school hierarchy plays a more important role.

[8] Although leadership in terms of school hierarchy does not play a role in the Spanish and Catalan context, as it has been discussed, this does not mean that leadership is not an issue in these contexts. There are other forms of teacher leadership that are important within the bottom-up reform approach. As Little points out in her longitudinal study of leadership (Little 2003), the meaning of this term is context dependant: a different construction according to the political and reform "moment", its goals and strategies. For instance, in the previously described autonomous teacher group scenario of Publication 3, "teacher leadership" is understood as teachers' knowledge and competence to engage, support and empower colleagues in curriculum innovation, which is crucial for the success of the group work.

[9] In Catalonia, the new educational law moves in the direction of giving more management and decision-making capacity and autonomy to more professionalised principals and other school leadership positions.

reform, as it is within the school that the teachers' working culture develops. In addition, within the school, educational change has more possibilities to achieve success in terms of students' results (for instance, by all teachers following the same successful strategy). Luckily, the lack of an appropriate school organisation for leadership within the school also means that in the Spanish/Catalan context teachers have a lot of autonomy and do not suffer from the in-school accountability largely discussed regarding their European colleagues. In this sense, Spanish and Catalan teachers are freer to initiate or participate in innovation if they decide or are engaged to do so. This allows for a great variety of small-scale, either teacher or school-based initiatives, taking place. Publication 2 (Couso and Pintó 2007) included in this work explores examples o these situations.

From all the above, we can see that, regarding who originates and supports educational innovation in the Spanish/Catalan context, there is a wide *spectrum* of possibilities (see Figure 1).

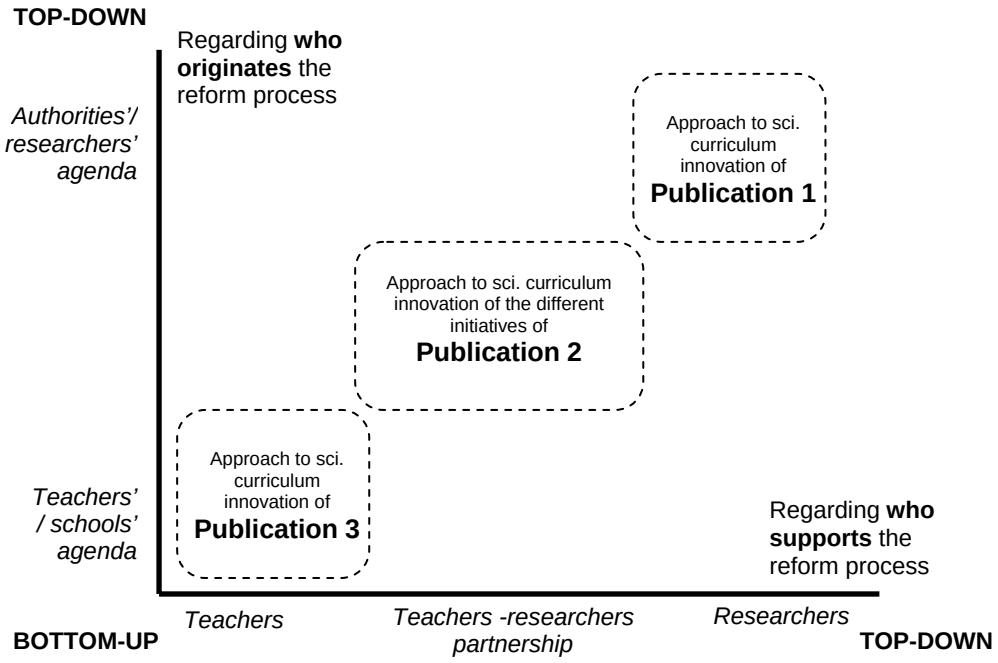


Figure 1: Qualitative representation of the top-down or bottom-up orientation, regarding who originates and who supports educational change, of the initiatives of science curriculum innovation analysed in Publications 1, 2, and 3 of this work.

However, there have been strong movements against this new trend and whether it is going to be effective or not it is still under discussion.

This *spectrum* goes from completely top-down initiatives originated and supported externally to the school, either by policy makers or researchers (like in Publication 1), to completely bottom-up scenarios originated and supported by schools or teachers themselves (like in Publication 3). In the middle area of this spectrum, there are examples of initiatives not easily classified as top-down or bottom-up, in which different sorts of university-school partnerships are organised. The second paper of this work (see Publication 2) explores examples of initiatives situated in this *middle-ground,* focusing on those which, by different means and in different contexts, try to have the described school-based locus. In this sense, Publication 2 includes initiatives in which educational change is initiated at the school level by teachers themselves but supported by a teacher educator on teachers' demand; initiatives in which innovation is driven by the political agenda with initial university support, but is later conducted by teachers themselves on their own, achieving certain sustainability; and initiatives originated by innovative teachers who struggle to involve colleagues from their schools in curriculum innovation, with different results. These scenarios, despite their variety, are representative of curriculum innovation small-scale initiatives with a bottom-up orientation in the Spanish/Catalan school context. Interestingly, in Publication 2 the exploration of school-based bottom-up innovation contexts is done from the teachers' instead of the researchers' viewpoint, analysing their perspectives of educational change in the above mentioned diverse scenarios, in an attempt to capture their voice (Goodson 1992) by making teachers participate in deliberation and discursive decision-making (Lang 2007).

Teachers' perspectives discussed in Publication 2 are obtained by engaging teachers in purposeful collaborative reflection, which means involving them in a shared and collaborative construction of their group view of bottom-up reform, rather than individual reflection. This is because the former is a much more powerful strategy for teacher development than the latter, allowing deeper reflective practice. In his review of the literature on the concept of teacher reflection, Zeichner (1994) points out an important distinction *"between those programmes of work that emphasize reflection as a private activity to be pursued in isolation by individual teachers, and those which seek to promote reflection as a social practice and public activity involving communities of teachers"* (p.11). Despite there is a great emphasis in the literature on reflection as a private activity to be carried out by individual teachers, there has been some attention on reflection as a social practice. According to Zeichner (1994) *"the lack of a social forum for the discussion of teachers' ideas inhibits the development of the teachers'*

personal beliefs because these only become real and clear to us when we can speak about them to others (e.g. Ross et al 1992, Solomon, 1987)" (p.12). In this sense, Publication 2 tries to disentangle teachers' view of school-based innovation so that we, but also the participating teachers, know more about this approach to reform.

The interest in the broad and varied contexts of innovation that this study deals with, as shown in Figure 1, is related to the very different professional development opportunities they provide to teachers. In the literature, there is certain agreement that teachers' involvement in ambitious innovation supply rich opportunities for professional growth, despite also being able to introduce the *seed of disappointment* on teachers (Huberman 1995; Little and Bartlett 2002). We agree with Lang and colleagues that in education *"different reform agendas embody images of different professional ideals"* (p.9, Lang, Olson, Hansen and Bünder 1999), that is, different views of the teaching profession and thus, of the professional development needed. In the same way that the selected contexts in this study provide a wide spectrum regarding teachers' participation in innovation, they are also scenarios where different knowledge and competences are expected to be mastered by teachers, and within with this knowledge and competences can be learn and developed in different ways. Publication 1, for instance, focuses on content, both subject matter and pedagogical content knowledge, as the main concern for teachers in order to innovate particular aspects of their science teaching. Within this reform agenda, the professional development of teachers is related with the learning of the aforementioned knowledge to teach science better. This is suggested to be done in traditional in-service teacher education settings which, despite being short-term and not-contextualised, have been shown to be successful when limited and very concrete scientific or didactic knowledge needs to be learnt and as a complement of other forms of professional development (Guskey 2000; Loucks-Horsley, Love, Stiles, Hewson and Mundry 2003). On the other hand, Publications 2 and 3 are situated within a different reform agenda, that of a professional who is not only knowledgeable and competent to implement successfully the curriculum, but who is able to control it. In Publication 3 teachers are cooperative curriculum designers who work together for innovating their science teaching by introducing an interdisciplinary and contextual approach. As has been largely discussed within the science education field, this is quite challenging for the subject specialist science teacher and requires new skills in curriculum making: the traditional *"competencies in science knowledge or acquisition of science facts alone are not sufficient for developing a curriculum concerned with broader visions of scientific literacy"* (p.178, Lang, Drake and Olson 2006). According to these authors, however, *"the capacity to engage in effective*

discourse with other teachers with other subject expertise is a critical first step" (p.178) undertaken by teachers in Publication 3. This makes participating in this context a potentially interesting professional development opportunity for them. In Publication 2, control of the curriculum takes a new dimension. Here teachers reflect collaboratively about how they participate in the process of school-based reform, thus situating their reflections at the meta-level. This implies not only teachers' knowledge and competence for developing innovative science curriculum but also knowledge and competence *about* this process. By reflecting on what conditions promote school-based reform and what conditions make it more difficult, teachers develop professionally in the sense of taking responsibility for their own, and also their colleagues*', "new"* professionalism (Hargreaves 1994b).

The above paragraphs have tried to justify the three scenarios chosen to form part of this work. Despite the aforementioned contexts and approaches of Publications 1, 2 and 3 not being completely comparable and homogenous; neither do they cover in detail all the spectrum of possibilities of science education reform and professional development scenarios in the Catalan context, from our point of view they form an interesting sample. This is because the aforementioned characteristics of these real examples of science education innovation show an evolution that is somehow parallel to the evolution, over the last decades, of the views of educational reform and professional development in the literature in the field. For instance, Publication 1 deals with teachers who teach, researchers who both design and research and a science curriculum that is just science; while in Publications 2 and 3 teachers are referred to as designers, reflective practitioners and colleagues; researchers become facilitators and supporters and the science curriculum tries to cross the traditional boundaries of the subject. In Publication 1 teachers' knowledge and competence is displayed inside the classroom, while in Publications 2 and 3 this is extended towards the staff room and inter-school's networks. In Publication 1 there is a focus on teachers' knowledge of science and didactics of science, while Publications 2 and 3 focus also on teachers' view of teaching and capacity of collaboration and reflection. Finally, Publication 1 deals with what is global and universal, while Publications 2 and 3 emphasise what is local and contextualised. All these, among other characteristics of the aforementioned research works of Publications 1, 2 and 3, will be elaborated further in the following sections to justify their inclusion in being part of this research study on science teachers' professional development in a range of situations of curriculum innovation.

Research Purpose

The purpose of this research is to examine the relationship between educational innovation and professional development in Science Education. The aim is to provide a theoretical and empirically based model for the professional development of science teachers in contexts of innovation. This is done by analysing how different scenarios of science education innovation promote different aspects of the professional development of the participating teachers.

In this research work, we try to answer the following research question both doing a theoretical and empirical analysis:

- What can be a model for effective professional development of science teachers in contexts of educational innovation?

Such a model is based both on the characteristics found when analysing a variety of scenarios of science education innovation which promote the professional development of the participating teachers, and on the characteristics discussed in the literature for

effective professional development. In this sense, this research question can be divided into two, referring to the two different analyses to be done:

- How does this model (for effective professional development of science teachers in contexts of educational innovation) relate with the extensive theoretical contributions and research results in the field?
- What empirical contributions to this model (for effective professional development of science teachers in contexts of educational innovation) can be made from the research results of three pieces of research (Publications 1, 2 and 3) that explore aspects of professional development in different contexts of innovation, from top-down, short-term and research-based teacher training proposals to bottom-up, on-going, collaborative and reflective curriculum and meta-curriculum development initiatives?

Thematic Unity of the Research

The research work presented here is a compendium of three different published research papers. Each of these papers, written as independent research reports, has its own theoretical and methodological framework according to its context and the specific research problem they try to solve. However, despite the necessary significant differences among them, they also share central aspects of their theoretical background and methodological approach, which justifies the thematic unity of this compendium.

In the following sections, these common views will be further elaborated with the aim of providing a common theoretical framework for the compendium. This common theoretical framework will show the particular view of teacher professional development hold in this research.

4. Teacher professional development

> "These are changing times in education systems around the world. With the start of the new millennium, many societies are engaging in serious and promising educational reforms. One of the key elements in most of these reforms is the professional development of teachers: societies are finally acknowledging that teachers are not only one of the "variables" that need to be changed in order to improve their educational systems, but they are also the most significant change agents in these reforms. This double role of teachers in educational reforms- being both subjects and objects of change- makes the field of teacher professional development a growing and challenging area, and one that has received major attention during the past few years" (p. 7)
>
> E. Villegas-Reimers (2003)
> *Teacher professional development: an international review of the literature*

4. 1. What is professional development?

Professional development is a very polysemous term. In the previous sections of this document, but also in the literature, we have referred to professional development either as a particular sort of activities, a dynamic process or a final goal. Professional Development is also the field of Education that proposes these activities, analyses this process and discusses its goals. As both a concept and field, it has evolved over the last years from traditional views to newer conceptions, due to research results and changes in theories and the educational agenda. In the following, we will discuss these very related but different notions and paradigms of the professional development concept, because there are different rationales behind this variety of meanings. Along this discussion we aim to unfold the particular definition of professional development that we hold in this work.

4.1.1 Professional development as activity, process and goal

According to the thesaurus of the Educational Resources Information Center (ERIC) database, professional development refers to *"activities to enhance professional career growth"*. In the case of teachers, this refers to the activities that cause the professional

growth of educators. This general definition has different meanings in the literature, according to different rationales. Depending on what we understand by professional development, different sorts of "activities" are the ones proposed to foster the different types of "professional" growth pursued.

In the literature it is quite common to refer indistinctively to professional development and teacher education, referring to professional development activities as activities of teacher education or teacher training such as training courses, workshops or seminars. As Guskey (2000) pointed out *"in the minds of many educators, training is synonymous with professional development"* (p.22). Within this view of professional development, this term has been used as synonymous to in-service or staff development, that is, to refer to the official provision of courses and other activities of teacher education available to in-service teachers. In a similar sense it is also quite often used the term continuous professional development (CPD), emphasizing the fact that these teacher education courses should be offered to in-service teachers along their professional life span, and not only to pre-service or novice teachers. Problematic of this view of professional development as just teacher education or teacher training activities is the fact that it narrows the field of possible initiatives and scenarios able to promote the professional growth of teachers. As Terhart (1999) said, teacher education or training is aimed at teacher development, but it is not teacher development in itself. In this sense, these professional development activities can just set preconditions for the development of professional competence, but are not the only source of it.

Contrasting with the previous view, other authors have referred to teachers' professional development as the process of teachers' professional growth *in itself*. Jackson (1992), for instance, defines professional development as *"the subset of changes [that inevitably happen along the teaching life of all teachers] which are desirable and positive in quality [such as] increasing ability, skills, empowerment, strength, knowledge, insight, virtue, happiness and others"* (p.63). In this definition, professional development is understood as an improvement process, leaving open what sort of activities or settings cause this improvement. Within this process-view, professional development is seen as *naturally occurring*, occupying in "time" and "space" all the professional life of the teacher. Teachers develop professionally along all their professional life span, in all the settings and activities that form part of their professional and also everyday life (Goodson 1992). This does not mean, however, that because professional development always happens (all teachers become better professionals along their teaching experience, whether they attend to training courses

and participate in innovation or not), it just happens in the desired ways, amounts or at the desired times. Within the process-view of professional development, how to foster from the "outside" this complex process which is extremely linked with the professional life and self of the teacher, reveals problematic. As Terhart (1999) points out, *"teacher development is a process in the course of which a teacher establishes and maintains the level of professional competence that is possible for him or her to reach. Teacher development can be facilitated and supported from "outside", but it cannot be produced in a technological manner*" (p.27). In this process-view of professional development, the professional growth of teachers is personal; involves gaining knowledge useful for the profession but also learning how to use this knowledge (professional competence), and is more related with participation within a rich and challenging professional life than with assistance to particular in-service training courses.

Finally, in addition to certain activities and a process in itself, professional development is a goal to achieve in education. The growing recognition of the importance of professional development has been mentioned before in the introduction. For some authors the situation can be referred to as historical: *"Never before in the history of education has greater importance been attached to the professional development of educators. Every proposal for educational reform and every plan for school improvement emphasises the need for high-quality professional development."* (p.3, Guskey 2000). Never before it was more recognised that teachers' quality affect students' results, neither that teacher quality can be enhanced through professional development. In this sense, the author defines professional development in terms of its goal: *"those processes and activities designed to enhance the professional knowledge, skills, and attitudes of educators so that they might, in turn, improve the learning of students"* (p.16).

The reasons behind the present historical interest in professional development, as it has been discussed, are quite related with the context of the modern educational reforms, which *"require teachers to transform their roles and take on new responsibilities"*. In this sense, professional development is necessary for teachers so that they can learn these challenging new roles and succeed in playing them. However, authors also point out that the focus on professional development is also a result of the rapid growing of the knowledge base of education, that is, of the inherent continuous development in the field. For Guskey (2000), *"as this knowledge base expands, new types of expertise are required of educators at all levels*". Like all professionals in any field, educators must keep abreast of this emerging and growing knowledge. This is

even more important for science teachers. On the one hand, Science Education has consolidated as a field of research (Gil, Carrascosa and Martínez 2000; Fensham 2004) and autonomous discipline (Adúriz-Bravo and Izquierdo-Aymerich 2002), providing an extensive didactical/pedagogical knowledge base that continues growing. The particular STS and scientific literacy approaches that most reforms share worldwide demand a restructuration of the science subject that, for instance, stresses the value of knowing science but also about science (Duschl 1990; Millar and Osborne 1998). In addition, the knowledge base in the science field is also expanding and the scientific knowledge that is considered socially relevant does not stop changing. In this sense, we strongly agree with Guskey (2000) that the demand for increased professional development is not an indication of deficiencies in the knowledge and skills of classroom teachers. On the contrary, the current emphasis on professional development comes *"from growing recognition of education as a dynamic, professional field"* (p.16). As the professional responsibilities, roles and knowledge base for the profession of teaching expands, practitioners need to be prepared to refine their knowledge and skills.

According to all the above mentioned, teacher professional development is referred to either as teacher education activities for professional growth; the process of professional growth that can be promoted by teachers participating in demanding and extended innovative initiatives and the goal of professional growth in itself, all of them aiming to increase students' results (See Figure 2).

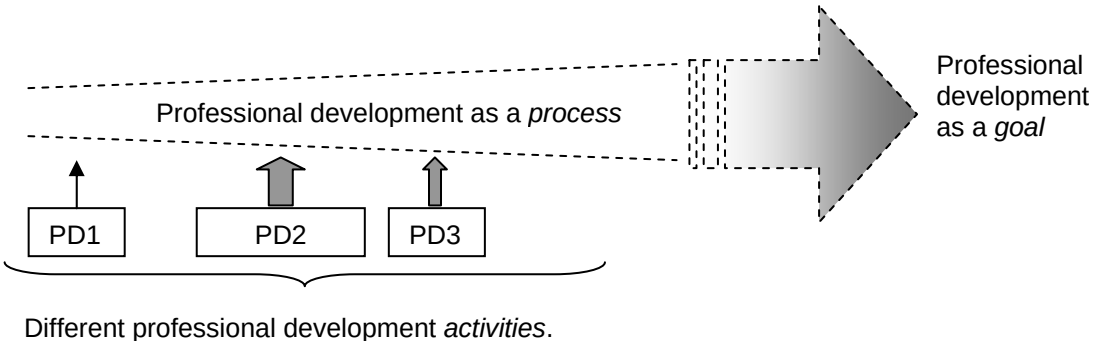


Figure 2: Different common meanings of the term professional development (PD): professional development as activities that promote it, as the process or as the goal of professional growth.

All these three notions and meanings of professional development coexist in the literature and have been used in the previous sections indistinctively. There are, however, traditions of professional development that resonate more with the view of professional development as particular activities or as a process linked with teacher professional practice. In the following sections, these traditions and the evolution of the notion of professional development towards new conceptions will be explored.

4.1.1. 1. Professional development within the "training paradigm"

What is generally referred to as traditional professional development is the professional development initiatives designed within the so-called *"training paradigm".* The rationale behind this paradigm has been described as that of establishing a bidirectional and univocal relationship between initiatives of in-service teacher training (or traditional teacher education) and the professional growth of teachers. Within this paradigm, it is considered that the traditional short-term and standardized sessions typical of staff development courses, workshops and seminars are the main source (or even the only source) of teacher development. Or in other words, that teachers mainly (even only) learn and develop along the official provision of in-service courses. As some authors have pointed out, traditionally professional development has been conceptualized as basically a dissemination activity: "*locate new knowledge relevant to teaching, package it in an attractive manner, and get it into the hands of teachers"* (p.194, Wilson and Berne 1999). For Ingvarson (1998) this *traditional system* of professional development is not only a model of in-service training, but something much deeper: a system within a particular reform agenda characterised by employers having control, governments establishing the goals, the leading actors being universities or consultants and the models of professional development used being usually short-term courses or workshops, which of course are not necessarily related to practical issues (Villegas-Reimers 2003).

The critics to this paradigm, extensive over the last two decades, have been originated from despairing research results analysing the impact of in-service training programmes in educational change. Authors have suggested different reasons for failure. For Guskey (2002) and others, the majority of these programs did not take into account two crucial factors: what motivates teachers to engage in professional development and the process by which teachers change. According to the author, *"many conventional forms of professional development are seen as too top-down and too isolated from school and classroom realities to have much impact on practice"* (p.3, Guskey 2000). In this sense, McLaughlin (1991) refers to professional development

activities offered within the “training paradigm” as *"activities planned and developed far from the school site, with insufficient relevance to [...] classroom practices and inadequate follow-up to permit integration of new ideas and methods into professional activities"* (p.62).

Some traditional in-service training activities have also been criticised for being of poor intellectual and motivational quality. For some authors, many staff development courses communicate an impoverished view of teachers and teaching. Compared with the complexity, subtlety and uncertainties of the classroom, in particular when change is pursued, much in-service training has been described as a *low intensity enterprise* that requires little involvement (little intellectual struggle, emotional engagement and participation) from teachers (Little 1993). This fact is even worse when professional development is organised for helping teachers to cope with the new demands bottom-up education reform is posing to them. For the author, these sorts of activities are not able to *"deepen the discussion, open up the debates, and enrich the array of possibilities for action"* (p.148) that are necessary for teachers if they are expected to move beyond a *mechanical use* of the curriculum. Huberman (1995) found that, according to teachers, the most robust opportunities for teachers’ professional engagement are found in ambitious innovations, in particular when they are undertaken with colleagues.

Other authors have emphasised the idea that traditional professional development does not take into account what we know about how people (how teachers) learn (Gil 1993; Porlán and Rivero 1998; Ball and Cohen 1999; Putnam and Borko 2000; Borko 2004). These traditional training initiatives have been discussed as having more a “transmission-oriented” (the dissemination approach already mentioned) than a constructivist or socio-constructivist approach. For instance, traditional in-service has been described as unlinked with teachers’ interests, previous knowledge and individual scope, besides fragmented and sporadic. From a *situative* perspective of learning (Putnam and Borko 2000), today we also know that teachers learn[10] different things in different contexts, including their own classroom practice, the collaboration with colleagues or other more sophisticated practices that enlarge teachers’ professionalism beyond the classroom door. According to teachers’ themselves, the professional development activities that help them best to develop professionally are *“observing other colleagues; collective enquiry into school improvement; taking part in coaching or mentoring; high quality training on specific skill areas, with excellent teaching materials*

[10] This point will be elaborated longer, in a following section about teacher learning.

and direct support to apply learning in classrooms" (*White paper on teaching and learning* 2000, cited in Bolam, McMahon et al. 2005). These initiatives are collaborative, school-based and classroom-oriented professional development. As we will discuss in following sections, the literature reviews about effective professional development also stress these characteristics as the more effective ones (Putnam and Borko 1997; Loucks-Horsley and Matsumoto 1999; Wilson and Berne 1999; Supovitz and Turner 2000, Borko 2004).

The above mentioned does not mean that teacher training activities are not useful. Under the right conditions, training-based staff development approaches have shown to have good results regarding discrete knowledge, skills and techniques (Villegas-Reimers 2003) and as such, are included in recent reviews as one of the possible designs of professional development activities (Guskey 2000; Loucks-Horsley, Love et al. 2003). The problem is that, unfortunately, quite often this approach has become the dominant or even the only one available for supporting the professional growth of teachers, much beyond the domains in which it can be effective. As we have mentioned before, this is particularly problematic in the present reform scenarios, because it becomes more obvious than ever the problem of *"fit"* between the challenging reform agenda and this limited prevailing configurations of teacher training (Little 1993).

4.1.1. 2. Moving beyond the "training paradigm": the new conceptions of teacher professional development

Over the past two decades, there has been a paradigm shift gathering momentum with regard to the professional development of teachers. "*Fuelled by the complexities of teaching and learning within a climate of increasing accountability, this reform moves professional development beyond merely supporting the acquisition of new knowledge and skills for teachers"* (p.80, Vescio, Ross and Adams 2008). This new paradigm has been described as a "*much broader and appropriate way to respond to the professional development needs of teachers through their careers"* (p.66, Villegas-Reimers 2003). This new view of professional development resonates with the notion of professional development as a process, and as such, improvement here is not restricted to happen in particular moments due to particular activities, but along the complete professional life of teachers, in an ongoing manner, across a great variety of experiences.

In this sense, within the new notion of professional development, one should refer to professional development experiences, initiatives, scenarios, contexts or settings rather than to particular training activities. Besides, different notions of teachers as reflective practitioners, as mentors, as coachers, as curriculum makers, as action researchers, etc. emerge as part of the professional development field. This is because some experiences not organised as training activities, such as involvement in curriculum writing, peer collaboration, action research or mentoring, among others, have shown to have a strong impact in the professional development of the participating teachers: *"professional development can (and usually does) occur during many activities that are not intended primarily for that purpose"* (p.68, Villegas-Reimers 2003). For Glatthorn (1995) this implies *"the provision of organized in-service programmes designed to foster the growth of groups of teachers it is only one of the systematic interventions that can be used for teacher development"* (p.41), and in this sense, other forms need to be explored. Other authors have made the point of considering part of professional development not only different formal but also informal experiences, such as teachers' collegial exchanges (Fullan 2001). Within this extended view of professional development, the link between professional development and educational innovation that we want to analyse in this work becomes more relevant: innovation can be a very rich and challenging professional development scenario, even if it is not designed with that particular purpose.

We consider that, despite a possible interest in informal scenarios, an important idea to keep in mind when looking at professional development is that of *systematic intervention* (Villegas-Reimers 2003). We agree with authors that have urge caution regarding the fact that broadening the view of what constitutes professional development should not imply that any form of peer work or any use of teacher reflection should be seen as a potential professional development scenario. When looking at professional development, one must examine the content of the experiences, the processes by which the professional development occurs and the context in which it will take place (Ganser 2000, *cited in* Villegas-Reimers 2003). Not everything a teacher does help him or her to develop professionally in desired ways.

According to Guskey (2000), within this new paradigm professional development is seen as an intentional, ongoing and systemic process.

Professional development as an intentional process

Whether in formal or informal settings, self or externally organised, professional development should be designed and managed as a conscious effort to bring about positive change and improvement. Professional development is not, then, *"a set of random, unrelated activities that have no clear direction or intent*" (p.17). For the author, true professional development is a deliberate process, guided by a clear vision of purposes. It needs to be both "*strategic and intentional*", as it is argued in a recent revision of best practices for professional development, because what particular professional development design is necessary in any context it has to be decided (Charles and Shane 2006). In this sense, Guskey highlights the importance of planned goals for professional development: *"these goals form the criteria by which content and materials are selected, processes and procedures developed, and assessment and evaluations prepared"* (p.17). Others, however, object to the detailed specification of purposes and goals for professional development because this fact could narrow learning options and limit possibilities. As it has been said, and it will be analysed in greater detail in a following section, a great deal of teachers' learning takes place informally while working. However, this not necessary means that professional development takes place, regarding the positive connotation this concept holds. With or without defining specific learning outcomes for teachers associated to particular professional development scenarios, it is clear that if professional development opportunities are identified in advance and consciously used for learning purposes, their use will be more effective (Villegas-Reimers 2003). What is expected to be learnt would be made public, and thus, able to be revised and discussed.

Professional development as an ongoing process

As it has been stated before, education is a dynamic professional field with a continually growing knowledge base, particularly in the case of science education. In this sense, the need for teachers to become lifelong professional learners is an idea inherent to the new view of professional development. On the one hand, teachers need to keep abreast of novelty, that is, the new educational ideas, theories and research results. On the other, perhaps more important even, teachers *"must constantly analyze the effectiveness of what they do, reflect on their current practices, make adaptations when things are not going well, and continually explore new alternatives and opportunities for improvement"* (p.19). In this sense, the new view of professional development is that of an ongoing, job-embedded process where every working day presents a variety of professional learning opportunities when reflection

and inquiry on practice takes place. The challenge for professional development design and management is how *"to take advantage of these opportunities, to make them available, to make them purposeful, and to use them appropriately*" (p.19, Guskey 2000)

Professional development as a systemic process

"Harsh lessons from the past have taught educators that fragmented, piecemeal approaches to professional development do not work" (p.19). This is mainly due to one reason. These professional development opportunities offer no guidance about how the new strategy (or knowledge, or educational goal,…) fits with what is being done at the moment in the classroom neither in the school. In fact, what is being done (or known, or aimed at,...) or where (in which institutional context) is not generally taken into account. *"As a result, educators end up trying to implement innovations that they do not fully understand in organizations that often maintain structural or procedural barriers"* (p.20) In the same way that within the literature in educational reform there were calls for a more systemic approach that include teachers (and even other staff members, parents, etc.) in the process, authentic professional development also calls for a systemic approach that takes into account all levels of the organization. *"If changes at the individual level are not encouraged and supported at the organizational level, even the most promising innovation will fail"* (p.21). For the author, this particular fact of seeing professional development as a systemic process *"is a major paradigm shift for educators, requiring them to think about professional development in new and different ways"* (p.22).

We agree with Guskey that the systemic view of professional development, clearly associated with the *extended* role of the teacher in bottom-up reform approaches, is what most dramatically has affected the new views of professional development. These ideas have connections with the pioneering work of J.I. Goodland and his *teaching outside the classroom door.* In a review of Goodland's work, Fenstermacher (1999) points out that the most fascinating implication of his works were realising that *teaching* (or the work of the teacher) occurs not only on one side but on both sides of the classroom door, because teaching involves working with students but much more than that. In the new view of professional development, promoting it involves enhancing teaching effectiveness but also *"supporting [teachers] professional growth – that is, permitting the transition to roles of higher status and responsibility within the teaching profession"* (Villegas-Reimers 2003). This refers to the new roles of teachers as curriculum designers, practitioner researchers, inquirers of practice, etc. that have

been mentioned as the roles demanded by bottom-up reform, which need particular professional development initiatives to support them. According to Little (1993) and McLaughlin (1994), in these new reform scenarios the professionally developed teacher is the one who have not only grow professionally regarding classroom-related knowledge, skills and judgement, but also regarding the contribution to a professional community: learning how to cooperate and work, reflect, learn and decide with colleagues. Leithwood (1992) adds to this the importance of learning and developing to exercise leadership, which has been discussed as crucial and necessary to be constructed in these scenarios (Little 2003)[11].

4.1.1. 3. *New* view of professional development in our publications

The scenarios of professional development proposed or used in the set of publications that form part of this thesis are varied, according to the mentioned characteristics of *new* professional development. None of them share all the mentioned characteristics, that is, being intentional, ongoing and systemic, but each of them is a good example of a particular focus on each of them.

The professional development initiative proposed in Publication 1 (Pintó, Gutiérrez and Couso 2000) is characterised by being a highly intentional approach, in which there is careful planning of teacher education activities and its sequence, according to particular learning goals. For the design of the professional development initiatives of Publication 1, both theoretical ideas regarding teachers' learning and particular research-based results regarding teachers' knowledge and use in practice of the idea of energy degradation are used. The sort of learning and change in practice expected takes some time, as it is acknowledged by the fact that a series of activities in a workshop are planned and recommended to be organised with some time in between. However, we can not say that this is an example of an ongoing professional development opportunity, but the contrary. These sort of professional development sessions are generally planned as an occasional or one off event. In the same way,

[11] We have discussed in previous paragraphs that the school micro-political situation in our context does not allow an understanding of leadership in hierarchical terms, associated with images of headteachers and principals. However, the literature offers also other definitions of the term. It is generally considered that promoting teachers' leadership, in the sense of promoting teachers' empowerment (teachers' willingness and capacity) to play an active and leading role in curricular innovation and reform, is needed if efficient and sustainable change is pursued. It is in fact one of the ways of making the best of this human resources in education. We refer to this meaning of leadership in the following.

Publication 1 does not aim to have a systemic impact. It is addressed mostly to the single teacher, to its learning and practice within the science classroom. As such, it does not help teachers to explore other aspects of the teaching profession neither tries to have an impact at school or institutional level.

On Publication 3, on the contrary, there is no conscious intentionality in the design of the initiative as a professional development scenario. The context of Publication 3 is that of a self organised group of science teachers and teacher leaders designing innovative curriculum. Being the aim of the group the design of curriculum materials in itself, they do not show a conscious intentionality towards teacher professional development and learning. However, this does not mean that learning and development does not take place neither that teachers are not conscious of it. Within the curriculum development activities of the group, teachers' talk express explicitly what aspects are new to them and what they are learning from each other[12], in particular regarding teaching methodologies and subject-matter. In this sense, the lack of intentionality towards professional development of the initiative of Publication 3 is related to the fact that there is no explicit definition of self-learning or self-development outcomes by the participating teachers. However, as it is seen in the metacognitive discourse of some of the participating teachers, this does not mean that there is not a clear sense of direction. Particularly for the teacher leader coordinating the group, but also for other experienced participating teachers, it is clear the sort of curriculum materials they want to do (they speak about its rationale) and the image of the professional and teaching practice (what sort of teacher and teaching) they consider appropriate. They refer to it both explicit and implicitly in their discourse, showing a certain distribution of leadership.

Regarding the other aspects that characterise new professional development, due to the fact that the group of teachers of Publication 3 does not belong to the same schools and participate in this initiative in a volunteering, personal manner, we can not say that this initiative is addressed to have a systemic impact regarding the school. However, by

[12] Being observant participant of this group during long periods of time has also allowed the author of this work to realise that professional development also takes place. Change is perceived from initial meetings in which the sort of classroom material pursued is not a shared meaning among all participating teachers, and thus it needs to be made explicit, to more recent meetings were all teachers work in a coherent framework and there is no need for continuous clarification of rationale. The discourse analysis of the first meetings available in publication 3 of this work shows this initial state, despite the evolution of the group to the present is not part of this particular study.

participating in this experience, teachers are developing their social capacities of cooperative work and shared decision making, being this social part an important characteristic of the professional development potential of this context. On the other hand, this scenario is a clear example of ongoing professional development. Participating teachers have been working together for years, establishing a reflective and inquiring culture that allows them to continue working together even with changes in membership and leadership[13], designing new materials, testing them on practice and refining them. In this sense, this professional development initiative is job-embedded in the extra job these teachers involve themselves into doing: the job of cooperatively designing innovative science curriculum.

Finally, the initiative analysed in Publication 2 is a mixed approach. Again, there is a strong intentionality from the part of the organisers of the particular setting in which teachers are invited to participate in collaborative reflections. Teachers are asked to elaborate individual reflective narratives, discuss in small groups about educational change, and agree on their views of this process with a clear professional development purpose: that of making teachers more conscious of (and thus more empowered regarding) their actual and possible roles in different innovation and reform scenarios. This is done in a series of sessions, but not in a real ongoing manner. In this sense, there was not enough time allocated for the reflective collaborative culture to become the normal working culture of the group of participating teachers. However, this was not the objective of the initiative. The sort of collaborative reflection pursued, done at the meta-level among teachers from different schools, does not need to be part of the everyday work of the participating teachers. But is something important for them to do at some moment, as a way of constructing and raising their voice in the educational scenario. In this sense, the professional development initiative of Publication 2 had a strong systemic orientation. The collaborative reflection was organised around a purposeful selection of different examples of school-based curriculum innovations, some of them systemic (involving the complete school or science departments) while others were struggling to achieve a more systematic profile, to help them elaborate their views on these issues. In addition, teachers were also asked to explicitly discuss and reflect about innovation and educational change within broader social and political scenarios than that of their classrooms and schools. Issues of identity, leadership,

[13] Again, some of these characteristics regarding the development of teachers' working culture are reported from the observations of the author while participating in the group. They would be part of a longitudinal study of the group work, still on process, which is not included within the three publications part of this dissertation.

school community and teachers' roles in education emerged, thus making teachers develop their views on them.

According to all the above mentioned, each of the innovation scenarios analysed in the publications that form part of this compendium highlights one of the characteristics of the new view of professional development discussed, that is, it is an example of an intentional, ongoing or systemic approach. Figure 3 tries to represent this fact. Theoretically, an interesting professional development scenario seem to be one that manages to integrate the sorts of training sessions of Publication 1 within an ongoing activity of extended professional development, such as that of Publication 3, with a systemic orientation, for instance being school-based and/or dealing with social and political issues like in Publication 2 . More on these ideas will be discussed in following sections.

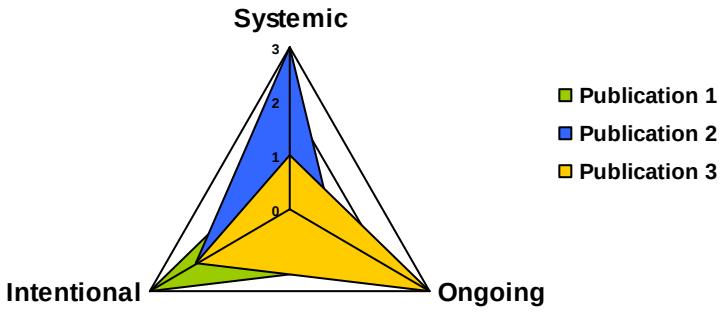


Figure 3: Representation of the caracteristics of new professional development in Publications 1, 2 and 3 of this study.

4.1.2 Designs of professional development

The new view of professional development has led to new professional development designs[14]. Early descriptions from Sparks and Loucks-Horsley (1989), also supported more recently by Guskey (2000), speak about five main designs of professional

[14] In the literature, these are often referred to as "models" of professional development, rather than designs. However, we consider a model for professional development to be something more general, able to be used in a variety of situations. In this sense, we refer here to designs of professional development while the aim of this research is to offer a model inspired in certain characteristics of these designs, among other influences.

development which are currently being espoused and used in practice. The authors discuss the supporting theory and research on these designs and the organizational context that is required to support these particular successful staff development efforts. These major designs are: training, observation/assessment, involvement in a developmental/improvement process, study groups, inquiry/action research, individually guided activities and mentoring. In the following, we will briefly describe some of these "families" of professional development, due to the fact that the professional development scenarios proposed or analysed in the publications of this work belong to one of them or share characteristics of some of them.

Training

The rationale behind a training design of professional development has already been discussed, as it is the central, almost only possible design of professional development within the training paradigm. This form of professional development it is the most common one, in fact, the one with which educators have the most experience. A part from the traditional training formats of seminars and workshops, which generally deal with new *knowledge* (in the sense of theoretical knowledge), there are other forms of training more related with the learning of new teaching skills and practices, such as demonstrations, micro-teaching, etc. which, despite their "behaviouristic" root, have shown effective for concrete and small-scale educational aims, in particular for initial teacher education. Despite the mentioned critics to this paradigm, training has been discussed as the most efficient and cost-effective professional development design for sharing ideas and information with large groups of educators: *"It provides participants with a shared knowledge base and a common vocabulary"* (p.23, Guskey 2000). However, the major shortcoming is that it offers few opportunities for contextualisation and, as mentioned, that does not always takes into account how teachers learnt.

Observation/assessment

Many examples of professional development opportunities, starting from the practicum activities within pre-service teacher education, are based on the idea that *"One of the best ways to learn is by observing others, or by being observed and receiving specific feedback from that observation"* (p.23, Guskey 2000) It is not that the observation *per se* causes learning and development in a behaviouristic way, but the analysis of and reflection on others or one self's practice can be a valuable mean of professional growth. Examples of this strategy are peer-coaching, mentoring, and clinical supervision. Research in the field of both pre- and in-service teacher education

have shown that these observations provide important benefits to both the observer and the one being observed (Philips and Glickman 1991; van Driel, Beijaard et al. 2001). When organised for in-service teachers, it also help breaking down the isolation in which teachers usually live in their working places (Clandinin 1986; Perrenoud 1995), strengthening the present or becoming the seed of a new school community culture. As other sophisticated forms of professional development, it requires commitment of significant time, coordination of schedules and, very important in most new professional development designs, trust among colleagues to be able to achieve the *"critical colleagueship"* necessary for these opportunities to be effective (Lord 1994).

Involvement in a development/improvement process

Educators are often brought together to be involved in educational innovation, for instance, by developing or reviewing a curriculum, designing a new program or planning new strategies to improve instruction, among others. As we have been discussing from the beginning of this work, these scenarios can promote professional development in rich ways. In this sense, Sparks and Loucks-Horsley (1989), Guskey (2000) and others include them within their reviews of professional development designs. For the authors, despite these scenarios have other purposes than professional development, they can have a strong impact on the professional growth of teachers. This is because they require from teachers to acquire new knowledge or skills through reading, research, discussion, and observation, among others.

As we have argued along this work, and particularly, when discussing the professional development potential of the scenario of Publication 3 of this compendium, *"The advantage of involvement in a development/improvement process is that participants not only increase their specific knowledge and skills [for teaching], they also enhance their ability to work collaboratively and share decision making"* (p.24, Guskey 2000). In this sense, these opportunities allow teachers to develop both for their work within and outside the classroom, within a new, more participatory and democratic school culture. This view is also referred to as *transformational teaching*, related to teachers' participation in curriculum design, which has shown to have deep implications in teacher professional development (Parke and Coble 1997). Of crucial importance of these scenarios is also the motivational factor. While training activities have been discussed to be about issues not necessarily interesting for teachers, participants in this form of professional development generally have strong interest in the problems and issues they address, quite often decided by themselves, and hence

are personally committed to finding workable solutions. In fact, within the development/improvement processes the *new* work to do has direct relevance to teachers' professional responsibilities, and as such, is not just another *extra,* perceived as irrelevant, work. In addition, as we have also discussed before, these participatory (bottom-up) scenarios are not only the best for teacher professional development, but for the success of the innovation itself: *"because they [teachers] are closest to the context and often understand it best, the solutions or strategies they develop are more likely to succeed"* (p.25, Guskey 2000).

Despite its benefits, involvement in development/improvement process, as most new designs of professional development that address individual and institutional needs, present an important shortcoming: benefits are generally restricted to a relatively small portion of teachers. Other drawbacks have been found, too, when these professional development practices are not well-guided and facilitated by knowledgeable teacher leaders, teacher educators and researchers. There is the danger that persuasively argued opinions take precedence over research evidence and knowledge of best practice (Hawley and Valli 1999). To be effective, participants must have access to appropriate information and expertise so that they can make knowledgeable and well-reasoned decisions. As we have also discussed before regarding bottom-up reform, school-university partnerships and other collaborative relationships are especially useful for these purposes.

Study groups

The study group design of professional development is a particular organisational strategy quite similar to the previous one, but generally organised at the school level with a problem-based orientation. In this sense, it relates with the idea of school-based reform. These study groups involve the entire staff of a school in finding solutions to a common detected problem, dividing members into smaller groups that analyse different aspects of the global problem with rotating leadership. Study groups bring focus and coherence to improvement efforts, especially if groups are carefully structured, well trained, and well supervised. *"Study groups reinforce the idea of schools as learning communities for students and educators alike and they emphasize the continual and ongoing nature of professional development"* (p.25-26). This source of professional development is based in the school and this makes it to have interesting systemic particularities at institutional level, such as higher impact in the school culture, better outcomes of students as a result of *everybody pulling in the same direction* and generation of local knowledge to solve real local problems, among others. In this

sense, it is a superior professional development design to the previous one, which addresses just the teacher level.

Some authors refer to “collaborative problem-solving” professional development instead of study groups (Hawley and Valli 1999). For the authors, this collaborative problem-solving is useful for breaking down teacher isolation, collectively empowering teachers, creating an environment of professional respect and the development of a shared language and understanding of good practice. In contexts were school-based innovation is difficult, as discussed previously for the Spanish context, these study-groups are more likely to be formed by teachers from different schools working on the same aspects.

Inquiry /action research

According to Guskey (2000), the action research/ inquiry design of teacher education *“helps educators become more reflective practitioners, more systematic problem solvers, and more thoughtful decision makers”* (p.26) by involving teachers in action or practitioner’s research and classroom or school inquiry. This design is having an important impact nowadays. On the one hand, despite certain cautions to the quality of the research produced (Huberman 1996), since its origins the paradigm of action or practitioner research has been discussed as, and has shown to be, promising regarding teachers’ professional development and educational change (Kemmis and McTaggart 1981; Elliott 1991; 1993). Action research is a complex field, as it can have various theoretical orientations (technical, practical or emancipatory); there are different schools and traditions (Kemmis 1997) and implies different types of individual and collaborative reflection (Zeichner 1994). In this sense, many different definitions have been proposed (Cohen, Manion and Morrison 2007). A basic one is action research as a systemic study that combines action and reflection with the intention of improving practice (Ebbutt 1985). For Kemmis and McTaggart (1981), action research implies to plan, act, observe and reflect more carefully, more systematically and more rigorously than one usually does in everyday life. This can have an individual or a collective purpose: *“action research is concerned equally with changing individuals, on the one hand, and, on the other, the culture of groups, institutions and societies to which they belong”* (p.16, Kemmis and McTaggart 1992). Regarding professional development, the importance of action research is basically related with the importance of reflection and metacognition (Baird, Fensham, Gunstone and White 1991) for teachers’ learning and change of practice, as we will discuss in following sections

On the other hand, there is a current push for an inquiry approach for student learning which is also influencing teachers' education. Originated as far as in Dewey's ideas (Barrow 2006), the inquiry approach has strongly permeated current science education reforms in US based on standards (NRC 1996; 2000), which are having an influence worldwide. According to these official documents, inquiry is the overarching goal of scientific literacy. In this sense, inquiry needs to form part of teacher education. For Barrow (2006), *"unless science teacher preparation programs provide an inquiry orientation to both their education and science courses, there will not be a major impact on seeing inquiry in K–12 classrooms"* (p.275). Then, regarding teachers', inquiry is not only one of the knowledge and skills to be learnt (for promoting scientific inquiry in the science classroom), but it is also an strategy for teacher development and learning they have to experience themselves. In our context, despite inquiry as a teaching approach for the science classroom has not been the focus in our official curriculum with the same strength as the English-speaking countries, researchers in Science Education have also discuss the benefits of this approach both for students' learning and teachers' professional development (Porlán 1993; Gil, Carrascosa et al. 2000)

The action research/ inquiry design of professional development has also been discussed as useful for narrowing the well-known research to practice gap. As Mellado (2003) summarises, the research with more education capacity and more possibility to have an impact on practice are not that made *for* or *about* teachers, but that made *by* and *with* teachers themselves. This resonates with the interesting view of the teacher as a *motor of change*, claimed by Villegas-Reimers in her international review (Villegas-Reimers 2003) and Gil and colleagues in their Spanish one (Gil, Furió and Gavidia 1998). This is also in coherence with the mentioned increase of teaching knowledge base. The fact that there are increasing expectations regarding teachers' knowledge (Guskey 2000) favours the view that professional development programs need not only to provide teachers access to it but mainly to help teachers learn how to continually access knowledge by researching and inquiring into their work and learning from others. "*Preparing teachers as classroom researchers and expert collaborators who can learn from one another is essential when the range of knowledge for teaching has grown so expansive that it cannot be mastered by any individual.*" (p.304-305). This means developing the skills to learn *from* practice (and *from* their colleagues) as well as to learn *for* practice (Darling-Hammond 2006).

Finally, we agree with Guskey (2000) that this inquiry/action research paradigm is greatly motivational. *"The overwhelming majority of educators are thoughtful, inquiring*

individuals who are inclined to solve problems and search for answers to pressing questions" (p.26). In this sense, the inquiry/action research design of professional development provides them with opportunities to do just that, helping teachers also to develop the disposition to continue to seek answers to difficult problems of teaching and learning.

Individually guided activities

Individually guided professional development activities refer to those activities which are self-directed or self-initiated by teachers judging their own learning needs and planning their own learning activities, according to their professional development goals. There are phases described in the literature for individually guided learning, such as identification of a need or interest, development of a plan to meet the need, selection of learning activities and assessment whether the learning meets the need (Sparks and Loucks-Horsley 1989). These phases could be followed informally, but the most interesting ones are those that form part of a structured professional development process.

This sort of professional development design has as it major advantages the motivation of teachers to participate, as they chose what they want to learn and how, and its flexibility, as there is complete adaptation to the individual teacher needs, learning style and context. Some well-known individually-guided designs are conducting personal narratives, journal writing, video self-assessment and individual professional development portfolios, among others.

The rationale behind this design is that learners should take control and responsibility of their own learning. In this sense, authors have pointed out that the titularity of professional development belongs to teachers, because development is in fact an internal process of self-development (Terhart 1999). The problem is that *not all teachers are aware of* this internal process and, according to the author and others, this awareness of one's own professional development (the going further, stagnation or regression) it is one crucial precondition for further development of professional competence (Hargreaves and Fullan 1992; Day 1999b). As a consequence, individually guided activities for professional development can not always take place and external support or other more interactive scenarios are needed.

The major problematic of this individually guided approach is the difficulty, then, of rigorous self-analysis, which research has shown as a critical factor for both teacher

and school change to have an impact on students' learning (Wasley, Hampel and Clark 1997). According to the authors, in the schools were teachers were not in the habit of scrutinize carefully their results, took personal responsibility for learning outcomes and search constantly for new ways to make improvements, results were much poorer, even though some self analysis was present. Another problem of these scenarios in which teachers decide what they want to learn and do is that a lot of *reinventing the wheel* can take place (Sparks and Loucks-Horsley 1989), in particular when this is done at the individual level without collaboration or professional sharing. However, the view of professional development as internal has an important consequence that the individually guided approach to professional development takes into account: the fact that each teacher would develop according to his or her own possibilities and context. Instead of normative models of ideal teachers in ideal worlds, which sometimes have guided teacher education, the professional development aimed for within this perspective is the one a real teacher can achieve in his/her real world/ context (Terhart 1999). We will see in following sections about teacher learning that this is in coherence with constructivist learning theory.

The above mentioned five[15] families or types of designs of professional development (Guskey 2000), based on previous works of Sparks and Loucks-Horsely (1989), were revised later by this author and others (Loucks-Horsley, Love et al. 2003). Focusing their review on professional development initiatives within the rationale of the *new* professional development (intentional, ongoing and systemic), the authors identified 18 strategies or designs particularly useful for the science and mathematics teacher (see Table 1), that, despite resonating with the previous ones and being based on similar ideas, are more detailed. These strategies include different forms of aligning and implementing the curriculum, different types of collaborative structures, different ways of examining teaching and learning, different immersion experiences (in the subject matter), different ways of practicing teaching and different vehicles and mechanisms for professional development.

In her review of the literature on professional development, Villegas-Reimers (2003) also identifies similar designs of teacher professional development, including certain techniques such as teachers' narratives, portfolios, etc. In her review the author divides

[15] In the review of models of teacher professional development of Sparks and Loucks-Hosrley (1989) and Guskey (2000) mentioned 6 types instead of 5, including mentoring. Here we have not addressed this last one because it is not relevant for the three cases of professional development within innovation scenarios that we analyse here, despite its importance as a professional development opportunity.

these more than 20 designs according to their scale and organisational needs, between:

- Models that require and imply certain organizational or inter-institutional partnerships in order to be effective.
- Models that can be implemented on a smaller scale (a school, a classroom, etc). This second group can be identified as *techniques* rather than designs.

Interestingly, many of the designs of the first group use the techniques listed in the second group. The importance of partnership or collaboration in professional development is very clear in this classification of professional development designs.

It is not our interest to go in detail here on each of the 18 Loucks-Horsley *et al.* (2003) types of professional development initiatives or scenarios, or the more than 20 Villegas-Reimers (2003) designs, because we are not designing or characterising professional development, but analysing how and where is considered to take place. In this sense, just seeing the variety within the five more important design families of professional development and the "unconventionality" of some of these designs when compared with the organisation of traditional teacher education, it becomes clear that something important is happening in the professional development landscape. The fact is that *"new and promising strategies for professional development have emerged"* (p.1, Loucks-Horsley, Love et al. 2003), widely broadening the view of how and where professional development takes place and can be supported. This is related with the *new* view of professional development discussed along all this section.

Interestingly, many of these new professional development initiatives are related with educational innovation and reform, which is the point we argue along this work. As we emphasised at the beginning of this work, the interest in exploring the link between both processes is what defines our sample, that is, the sorts of innovative scenarios we chose to analyse professional development. In this sense, it is interested that some of the designs mentioned in the cited reviews of professional development, such as involvement in a developmental/ improvement process, study groups, inquiry/ action research, aligning and implementing the curriculum or participating in collaborative structures, are also designs often being used for introducing innovations.

Science teachers' Professional development Models or Designs

According to the review of Guskey (2000)	*According to the review of Loucks-Horsley, Love, Stiles, Hewson and Mundry (2003)*
Training	**Vehicles and Mechanisms** - Workshops, institutes, courses and seminars - Technology for professional development - Developing professional developers
Observation/ assessment	**Practicing teaching** - Coaching - Demonstration lessons - Mentoring
Mentoring	
Involvement in a developmental/ improvement process	**Aligning and implementing curriculum** - Curriculum alignment and instructional materials selection. - Curriculum implementation - Curriculum replacement units
Study groups	**Collaborative structures** - Partnerships with scientist in industry, universities, etc - Professional networks - Study groups
Inquiry/ action research	**Examining Teaching and Learning** - Action Research - Case discussions - Examining student work/thinking - Lesson study
	Immersion experiences (as students) - Immersion in inquiry/problem-solving Immersion in the world of scientists
Individually/guided activities	*(any of the previous, at individual level)*

Table 1. Different designs (designs and techniques) for teacher professional development in science.

The described designs and others discussed in the literature should not be understood as normative models to follow. In fact, these designs are just referential: real professional development scenarios are generally more complex and continuous adaptation to purpose takes place. Because *"it is unlikely that any single model will prove effective for all individuals under all conditions"* (p. 29, Loucks-Horsley, Love et al. 2003), the appropriateness of any particular professional development design depends on its goals, the content and the context of implementation. In this sense, a professional development plan based on a combination of designs and strategies can

take advantage of the positive attributes of several designs and should evolve and change over time, emerging out of and being uniquely suited to its particular goals and the context in which it is implemented.

4.1.3 Effective professional development

Whatever the design or combination of designs of professional development used in a particular initiative or scenario of professional development, the interesting thing would be to analyse what characteristics of this design or scenario made it successful (or unsuccessful) regarding teachers' professional growth.

As it has been mentioned before, the literature on professional development is filled with descriptions and discussions of past failures. However, it is not the case that all professional development in education is ineffective, meaningless or wasteful: *"there are important exceptions to this dismal pattern. Strong evidence shows that some professional development efforts are highly successful"* (p.3, Guskey 2000). Some of this evidence has been obtained analysing the effect of professional development in the science classroom in particular (Kennedy 1998b; Supovitz and Turner 2000). In fact, over the last decade researchers and educators have forged a remarkable level of consensus about what may constitute effective professional development, not only in general, but also particularly in the science field (Putnam and Borko 1997; Loucks-Horsley and Matsumoto 1999; Wilson and Berne 1999; Supovitz and Turner 2000; Loucks-Horsley, Love et al. 2003; Borko 2004). In this sense, we focus here on the extensive research on what makes effective professional development, selecting well-known reviews in the field.

According to Wilson and Berne (1999) review of well-known, successful examples of professional development initiatives, effective professional development:

- Involve teachers actively in a community of learners (even best, learners in the subject).
- Is long-term
- Promote collaborative work, trust and reflection to achieve "*critical colleagueship"*
- Focuses on the goal of improving students' learning (qualitative and quantitative data)
- Brings closer educational research and educational practice.

The review of Villegas-Reimers (2003), in which the author tries to illuminate a *new* perspective of professional development strongly linked with new trends in educational reform, stresses the following characteristics of effective professional development:

- It is based on constructivism
- It is perceived as a long-term process
- It is perceived as a process that takes place within a particular context
- Many identify this process as one that is intimately linked to school reform
- Professional development is conceived of as a collaborative process
- Professional development is context-dependant

In the field of mathematics and science education, Loucks-Horsley and colleagues (2003) described effective professional development as:

- Being driven by a well-defined image of effective classroom learning and teaching (such as commitment to all children learning, inquiry-based learning, investigations, problem solving, etc…)
- Providing opportunities for teachers to build their content and pedagogical content knowledge and examining practice
- Being research based and engaging teachers as adult learners in the learning approaches they will use with their students (for example, start where teachers are and build from there; provide ample time for in-depth investigations, collaborative work, and reflection; and connect explicitly with teachers' other professional development experiences and activities)
- Providing opportunities for teachers to collaborate with colleagues and other experts to improve their practice, making continuous learning part of the school norms and culture.
- Supporting teachers to serve in leadership roles (for instance, as supporters of other teachers, as agents of change, as promoters of reform)
- Linked with other parts of the education system
- Being design based on student learning data and continually evaluated and improved.

Interesting to be highlighted are also the six critical components of "high quality professional development" proposed by Supovitz and Turner (2000) when reviewing commonalities of the last decade proposals. According to these authors, high quality professional development that is able to show impact in the science classroom:

- immerse participants in inquiry, questioning, and experimentation, and therefore, model inquiry forms of teaching.
- is both intensive and sustained
- engage teachers in concrete teaching tasks based on teachers' experiences with students
- is focused on subject-matter knowledge and deepen teachers' content skills
- is grounded in a common set of professional development standards and show teachers how to connect their work to specific standards for student performance
- is connected to other aspects of school change

A more recent review by Harrison, Hofstein and colleagues (2008) which includes the previous one and other well-known studies mostly within science but also in mathematics (Bell 1998; Ball and Cohen 1999; Putnam and Borko 2000; Borko 2004), highlight as features that characterise effective continuous professional development programmes:

- Engaging teachers in collaborative long-term inquiries into teaching practice and student learning;
- Situating these inquiries into problem-based contexts that place content as central and integrated with pedagogical issues;
- Enabling teachers to see such issues as embedded in real classroom contexts through reflections and discussions of each others' teaching and/or examination of students' work;
- Focusing on the specific content or curriculum teachers will be implementing such that teachers are given time to work out what and how they need to adapt what they already do.

Interestingly, there are some issues in common to all these reviews of effective professional development (See Table 2). Some have already been discussed as part of the *new* view of professional development being discussed in this section. These are, for instance, the long-term approach and the systemic view of professional development, which make professional development initiatives to extend in *time* (becoming on-going and long-term) and *space* (addressing the classroom but also the whole institutional educational context) to be effective. However, other characteristics of crucial importance for the effectiveness of a professional development scenario have not yet been discussed in enough detail. In the mentioned reviews, it is stressed the

importance of teachers' reflecting, examining and inquiring their practice, solving classroom or school problems, with the goal of improving students' learning. All these reviews also highlight the fact that professional development is more effective when it is designed as a collaborative process, stressing the importance of teachers' authentic collaborative work with notions of *critical colleagueship* for collaborative reflection, collaborative problem-solving and inquiry, etc. The importance of collaboration with experts, researchers or other agents is also mentioned for sustaining the development process and guaranteeing that it is research-based. In addition, most of these initiatives mention specifically the importance of professional development to be focused on or giving an important role to subject matter content, in particular, how the subject is expected to be taught. Finally, the most important of all characteristics of effective professional development is the fact that it should address teachers' learning, based on what we know about how people learn (constructivist approaches) and as a community of learners.

Characteristics of Effective Professional Development

- It is planned as a **long-term process** and it is sustained to become **ongoing**, possibly job-embedded.
- It has a **systemic view**: addresses both the teacher and the institution; takes into account the broader social and political context; it is linked with educational reform.
- It is focused on reflection and **inquiry** for solving problems of teaching and learning, classroom practice and students' results in an evidence-based manner.
- It is a **collaborative** process in which teachers and other necessary actors form a community.
- It is focused on the **subject**, on both content and pedagogical content knowledge.
- It takes into account what is known about **teachers' learning**

Table 2: Characteristics of Effective Professional Development according to the literature reviews of (Loucks-Horsley and Matsumoto 1999; Wilson and Berne 1999; Guskey 2000; Putnam and Borko 2000; Supovitz and Turner 2000; Loucks-Horsley, Love et al. 2003; Villegas-Reimers 2003)

In the following, we will briefly address each of these highlighted characteristics of effective professional development, discussing the crucial role of inquiry, collaboration and subject matter for the professional growth of science teachers. However, we will not address teacher learning here, due to the fact that it is a particular view of teacher learning what is actually behind a conception of professional development that highlights these strategies and characteristics. As we will discuss later on, effective professional development is described as ongoing, contextualised and systemic; based on reflection and inquiry, focused on subject matter and practice, and collaborative within communities, because these are all characteristics related to effective teacher learning and change within a particular view of teacher learning and change. This is not surprising: an interest in professional development is an interest in learning. Both processes are intrinsically related. There is no development without learning. In this sense, the promotion of ongoing or continuous professional development is strongly related with the notion of teaching as a *learning profession* and the school culture as a *learning culture* for both students and teachers (Darling-Hammond and Sykes 1999). Because teacher learning is such an important part of effective professional development, we will not address it here, but we will devote to it the entire next section of our theoretical framework.

4.1.3.1 Inquiry orientation in effective professional development

According to most of the mentioned reviews of effective teachers' professional development, this is linked to teachers problem-solving or inquiry into their practice. We have already discussed inquiry and action research as one of the main designs of professional development. However, according to the literature reviews above, an inquiring attitude appears as central to any effective professional development effort, rather than a particular design that promotes professional development. In this sense, it has been proposed that 21st century teacher education should be focused in teacher inquiry: *"This means that programs must help teachers develop the disposition to continue to seek answers to difficult problems of teaching and learning and the skills to learn from practice (and from their colleagues) as well as to learn for practice"* (p. 304, Darling-Hammond 2006). The idea is for teachers to adopt the positioning of *inquiry as stance*, that is, a questioning standpoint towards teaching and the profession (Cochran-Smith and Lytle 1999). In this sense, inquiry for effective professional development is not referring to a particular action research project a teacher is involved with for a short period of time, but a standpoint or a way of understanding the teacher job: a new conceptualisation of the teaching profession.

This positioning is not new in the literature and has its roots in the productive field of teacher reflection and the pursuit of a *reflective stance* in teaching (Zeichner 1983). Since Dewey, reflection is conceptualised as a form of problem-solving in which consideration is to be given to any form of knowledge or belief involved, and the grounds for its support (Hatton and Smith 1995). In her review of the field, Valli (1992) already claimed for this broader view of the concept of reflection, purposefully using "inquiry-oriented" as synonym for "reflective". Other authors (Copeland, Birmingham, De la Cruz and Lewin 1993) have also related reflection with the process of problem-solving and reconstruction of meaning, both in the sense of *inquiry as stance*. In the words of Schön (1990), cited by the authors: *"we view problem solving as a healthy, normal, and creative process in which capable practitioners attempt to make sense of puzzling or challenging phenomena, identify areas of practice that bear scrutiny, define particular goals for improvement, and pursue actions explicitly intended to accomplish them".* For Copeland and colleagues, then, reflective practice in teaching is manifested as a stance towards inquiry in which teachers identify problematic or interesting situations, generate solutions and deeper understandings, test these solutions and understandings and learn from these experiences. According to all the above, the inquiry approach suggested in effective professional development can be understood within a continuum that goes from the promotion of teachers' reflection on practice, on one extreme, to continuous practitioner research, on the other. As stated by Zeichner (1994), "reflective teaching", "action research", "research-based" and "inquiry oriented" are slogans of teacher educators and educational researchers, from a variety of conceptual and ideological orientations, which under the umbrella of reflective practice *"tried to prepare teachers who are more thoughtful and analytic about their work in some fashion"* (p.9). It is in this sense that knowing a little bit more what is teachers' reflection and how can be promoted is the first step in the fostering of an inquiry orientation for teachers' professional development.

The literature about reflection, product of the dominance of the cognitive and teacher thinking paradigm over behaviourism, is extensive (Valli 1992; Zeichner 1994). In this wide field, different interests and views of reflection have emerged. Hatton and Smith (1995) summarise them around four main dilemmas regarding reflection that have helped to clarify this process. First, researchers have discussed and researched whether reflection is limited to thought process about action or, on the contrary, it is more inextricably bound up in action. Despite it seems to be wide agreement that reflection is a special form of thought, the interest in the literature is concerned with

reflection coupled with professional "doing", because this latter one can lead to modified action. In fact, Schön's influential work describes reflection that is intimately bound up with action (1983; 1987). He referred to *"reflection-on-action"* and "*reflection-in-action*". The former notion implies looking back upon action to critically revise it. As such, it is a process that can be externally fostered and part of professional development initiatives. The latter notion of reflection-in-action, which involves simultaneous reflecting and doing, implies that the professional has reached a stage of competence where he or she is able to think consciously about what is taking place and modify actions on the way. In this sense, it could be the result of professional development and a personal source of it, but not part of a design of a professional development scenario or strategy. The second dilemma that research on reflection has dealt with is linked with the previous one. It regards when do reflection happens and whether it is relatively immediate and short term, or rather more extended and systematic. Again, while *reflection-in-action* is immediate, *reflection-on-action* can be extended in time and allows systematic approaches, which also makes them an interesting focus of professional development within a systemic approach. A third dilemma in the literature on reflection is the mentioned link between reflection and problem solving. While there is consensus that reflection is centrally concerned with finding solutions to real problems (Calderhead and Gates 1993), it is argued that the essential nature of reflection is thinking about action, whether linked to problems or not. For instance, the purpose of many reflection experiences, such as journal writing or narratives, is developing insights and understandings about the relations between what takes place, the purposes intended, and the difficulties which arise, without a particular focus on solving a specific problem. However, even in these scenarios, problems of practice are expected to be seen, found and solved through effective reflection, because this is connected with teacher learning from practice (Loughran 2002). Finally, the fourth dilemma is whether reflection should be promoted to be critical or not (Valli 1992), that is, whether it should take account of wider historic, cultural and political values or beliefs in framing and reframing the practical teaching problems to which solutions are being sought.

In the literature, there is also extensive discussion regarding types of reflection. Van Manen (1977) proposed three levels of reflection: technical reflection, practical reflection and, finally, critical reflection. Technical reflection is concerned with efficiency and effectiveness of means (what you do) to achieve certain ends, without criticism or modification of the latter ones. Practical reflection allows for open examination not only of means, but also of goals, the assumptions upon which these are based, and the

actual outcomes obtained. This kind of reflecting, in contrast to the technical form, recognises that meanings are not absolute but context dependant. The third level, that of *critical reflection* related with the previous mentioned dilemma, includes the previous two but, in addition, call for considerations involving moral and ethical criteria (Gore and Zeichner 1991). In this sense, it locates the analysis of personal action within wider socio-historical and politico-cultural contexts. Regarding the link between these levels of reflection and teacher education or professional development scenarios that foster them, Sparks-Langer (cited in Valli 1992) identifies either a *Cognitive Approach,* which utilises studies of teachers' information processing and decision making to guide professional development; a *Narrative Approach,* in which teachers themselves are asked to tell their own stories through problem framing, naturalistic enquiry and case studies; and a *Critical Approach,* which requires teachers to use ethical and moral reasoning, taking account to the social and political contexts. The last view of reflection as critical is particularly important not only because it allows teachers' to articulate and clarify their ideas or believes within a broader scenario, but because it gives voice to teachers' ideas so that they are heard by themselves and others in the educational arena (Goodson 1992; Valli 1992).

Some authors discuss that, despite different contexts in teacher education or professional development may lend themselves more to one level of reflection than another, it is important that the types are not viewed as an increasingly desirable hierarchy (Calderhead and Gates 1993), because all forms of reflection are useful for different purposes and one can be the precursor of the other. However other authors consider, within an "hypothesis of complexity"[16], that each of these types of reflection are more complex than the previous one, and that to use one or the other by a teacher is a personal election (Vázquez, Jiménez and Mellado 2007). Vazquez and colleagues use a metaphor of dimensionality to refer to each of these types of reflection of growing complexity. In this metaphor, while technical reflection is seen as an one-dimensional world of routine action schemes which fuel themselves for instance by trial and error, practical reflection is considered a superior two-dimensional world were more than one perspective is possible and solving-problems guides action. Finally, the critical reflection metaphor is that of a three-dimensional world in which problems of practice achieve the new dimensionality of the social axis. This growing complexity in reflection

[16] Within an "hypothesis of complexity", the authors analyse the multiple factors that play a role in the classroom, which are ideological, formative, psychological, contextual, epistemological and curricular.

is integrated with a growing complexity of teachers' practice, in a dialogic view of the relation between the two processes. According to this, the authors' model of teacher professional development is that of a series of *stadiums* in which the most concrete and superior one is that of choosing and achieving complexity both in teacher reflection and teacher practice, one informing the other. Interesting in the proposal of the authors is their agreement with the *emancipatory, critical* view for teacher reflection (Zeichner 1994) clearly stressing that it means, for the teacher, to assume and deal with the complexity of their profession and professional context.

Whatever the type, level, view or dimension aimed at, fostering reflection has also been reported as difficult. Four main problems have been encountered (Hatton and Smith 1995). First, reflection is not generally associated with the work of the teacher, that is, for many teachers this is not an intrinsic part of their work, as it is assessment or lesson plan. In this sense, for a focus on reflection an important change on the view of teachers' professionalism is needed. Second, reflection needs time and opportunity for development, so that the required essential metacognitive skills can be acquired (McNamara 1990; Gunstone and Northfield 1994). Some research results have shown that, even when reflection has proven successful for teachers, this does not mean that the process is mastered by them or immerse in their culture, so that it becomes sustained without the researchers or teacher educators' support (Loughran and Gunstone 1997). Third, there are problematic reactions to demands for reflection, related with a feeling of vulnerability and decrease of self-esteem when teachers are asked to critically review their practice. In this sense, authors generally advocate for collaborative forms of reflection, such as the notion of *critical friends* (McNamara 1990). A part from emotional and motivational reasons, collaborative reflection is also recommended regarding efficiency of reflection for teacher learning and professional development (Zeichner 1994). Finally, the structure and ideology of certain professional development and reform programmes, previously referred to as technical, does not support the development of reflection because within their framework it is not necessary: "*a critically reflective approach demands an ideology of teacher education different from that traditionally employed, which usually involves models of "best practice" [...] and unrecognised conflicts between institutional ideals and workplace socialisation"* (p.38, Hatton and Smith 1995)

To finish this section on professional development for a reflective and inquiring orientation to teachers' practice, it is interesting to focus on the related evidence-based teaching or practice approach. Evidence-based teaching means teaching according to

the evidences of students' learning process and results, which, a priori, is a desirable fact that most initiatives focused on reflection are fostering. However, evidence-based teaching could be done in different ways, not all of them appropriate for promoting teachers' professional growth. For instance, an inquiry orientation can become a successful strategy for teacher and school change or a perverse strategy serving self-accountability. In this sense, Hargreaves (2007) urges caution that the rationale behind evidence-based teaching should not be transformed in a purely data-driven instruction rationale, in which what is looked for is just a "quick fix" (by extra test preparation, out of school classes, concentration in low level students, etc.) to increase students' results and mask detected failures. On the other hand evidence-based professional development programmes, that is, programmes which require teachers to seek and identify evidence of practice in their own classrooms and analyse and reflect on it with colleagues and researchers, have shown to provide the impetus and motivation for teachers to transform their practice and are, thus, highly recommended (Harrison, Hofstein et al. 2008). Going back to the beginning of the section, it is the *inquiry as stance* approach, the questioning standpoint towards teaching and the teacher profession (Cochran-Smith and Lytle 1999), the one that gives inquiring, reflective and evidence-based practice its potential for effective professional development.

4.1.3.2 Collaboration in effective professional development

Another important aspect that all reviews of effective teacher professional development highlight is the importance of teacher collaboration. This is referred to with diverse concepts, such as community, cooperative work or colleagueship among teachers, and teachers and researchers, always referring to the importance of professional exchange and feedback among these different professionals. The importance of collaboration is also stressed regarding other useful strategies for teacher learning, such as the aforementioned reflection, which are also discussed to be more effective within collaborative environments (Zeichner 1994; Lang 2000; Manouchehri 2002).

According to Lang (2000), *"collaboration is a complex task dependent on mutual help, trust, openness, open access to various sources of information, reflective experiences from inside and outside school, and autonomy in a community of the individuals involved."* (p.10). As described, it is much more than mere collegiality or social interaction among teachers. The author defines collaboration as a special kind of personal and technical exchange for innovative educational planning. Behind this

notion there is a change of rationale regarding the scholar view of teachers' collaboration that has taken place during the last decades.

During the 90's, a lot of emphasis was placed on the idea of *"professional communities"* and the focus of interest was on how these communities form among teachers, promoting and analysing basically social interaction, collegiality and group cohesion. This focus on teachers' relations was a result of Hargreaves (1978) and others' complaints that, despite the extensive research on the relationships between teachers and students, or among students' themselves (particularly within the paradigm of peer work), there was almost no systemic research on the relations among teachers. However, a focus on mere collegiality and social life evidenced that focus and promotion of these two aspects alone did not have the expected impact on students' learning. In fact, research results showed that strongly cohesive teacher groups could have very limited interest or impact in changing their practice (Little 2002). For instance, a study confirmed that shared goals, joint decision making, shared responsibilities, consultation and advice, despite important, were insufficient to improve educational practice and, consequently, student achievement (Visscher and Witziers 2004). Rather, effects resulted when departments *"consistently translate their shared vision and willingness to cooperate into a system of rules, agreements and goals regarding teaching and instruction, and evolve their professional activities around this by obtaining data on student performance, which in turn serves as a feedback mechanism for improving teaching and learning. This differs from a 'softer' approach [to cooperative work]" (*p.798, Bolam, McMahon et al. 2005). In this sense, the interest in teacher collaboration and community has been reformulated towards an interest in these scenarios to improve teachers' professionalism and change in practice, that is, collaboration or communities for reflecting on, learning from or for, and inquiring on practice. Teacher collaboration and community goes far beyond than a mere gathering of teachers (Grossman, Wineburg and Woolworth 2000), if *authentic collaboration* (Couso 2008a, 2008b) is pursued.

The above mentioned implies that for professional development purposes is necessary to organise purposefully the new cooperative settings, establishing new norms of discourse and ways of working together, so that collaboration becomes useful beyond socialization purposes. For instance, to make explicit reference to classroom practice, the material artefacts used in it and the observed results (what is done, with what materials, what happened, etc), which is very important to promote opportunities for teacher professional exchange and cooperative learning, does not happen

spontaneously in teachers' interactions or group work (Little 2002). Collaboration needs, then, to be managed by teacher leaders or researchers helping to create the appropriate settings. For Haberman (1992) the collective implementation of change, that is, teachers' active participation in educational innovation, can be one of these settings where useful collaboration takes place. According to the author, these scenarios can have the fruitful by-product of fighting teachers' evidenced culture of closeness and professional isolation: *"teachers, much like other artists and artisans, typically stay away from one another's workshops. Within the school building, one does not ask spontaneously for help and one does not cavalierly offer advice. Both behaviours are reckless. To ask for help is publicly to compromise one's professional reputation (self-abasement); to offer help is to violate important norms of status equality (arrogance, hubris, bad form)"* (p.12-13). This has been referred to in the literature as the model of the independent artisan, certainly difficult to be addressed when it is the *status quo* of most schools (Huberman 1993). In this sense, it is important that in the process of enacting significant change, these norms can also modify. *"Since everyone is in over her head, no one is expected to perform well. Since we are all learning, making mistakes, finding solutions serendipitously, it is all right to ask for help and to give advice"* (p.13). However, collaboration would not arise spontaneously even in these facilitated settings of collective involvement in innovation and, again, collaboration needs to be managed. According to Darling-Hammond (2006), teachers need to be prepared to become expert collaborators who can learn from one another.

In addition, the organisation of cooperation has the objective to deal with conflict. Collegial work, interaction, community etc. invariable engenders conflict, either by bringing to a public forum pre-existing conflict (for instance in a school where there are past problems among certain people) or making hidden conflict to arise once teachers have to expose their views and beliefs of teaching and learning, subject matter, etc. We have to keep in mind that teachers are not only not used to work with each other, but generally purposefully avoiding to do so to avoid these situations in which different rationales and views of education emerge and confront (Perrenoud 1995). However, the emergence of conflict, if well-understood and managed, is not problematic for teachers' development in collaborative scenarios. On the contrary, for some authors it is not till some conflict is able to arise that a "pseudo-community" of teachers were there is a false sense of agreement does not start to become a real community (Grossman, Wineburg and Woolworth 2001). In this sense, the organisation of the cooperation has the objective to create a climate of *critical collegueaship* (Lord 1994), were critical discourse and feedback can be seen as something positive for one's

development. This is the main role of real cooperative groups or communities: *"When teachers come together for a day-long or even a week-long institute, the disciplinary and pedagogical issues we have encountered do not have time to surface. Only in a committed community, where individuals have the sustained opportunity to explore issues of teaching and learning with their peers, do such differences emerge"* (p.32, Thomas, Wineburg, Grossman, Myhre and Woolworth 1998) thus allowing to discuss them, think about them, reflect on them, negotiate them.

Research also shows that not all teachers' benefit equally from collaborative experiences. Experienced teachers, whose professional culture is related with independence and autonomy, norms of privacy and non-interference, etc. experience the greater difficulties in collaborative settings (Lortie 1975). It is common in research studies to report these experienced teachers as the ones facing more personal and professional conflict within the experience. They are generally those with bigger proportions of withdrawal from projects. Isolation for these teachers is chosen, is an option, the best one to work (Haberman 1992; Perrenoud 1995). However, they are also the teachers who acknowledge more the fact of being treated professionally (so this has to be accomplished) and also being allowed to discuss publically aspects of subject matter and practice with others. Because they have long belonged to the profession, they have form strong views on both aspects and their discussions are profound (despite sometimes quite imposing), and generally more focused on the actual curriculum development task and subject matter. For new teachers, the situation is a little bit different. Despite contextual differences in recruitment and organisation of new teachers, in most countries research reports that new teachers receive very few supervision and generally assume almost immediately the same responsibilities and tasks than experienced teachers have, with whom they have few contact. In general, new teachers' are more open to collegiality (they have been less socialized in the *isolation equals autonomy* culture) and generally have closer experiences from pre-service teacher education where working with colleagues was important. However, they focus much more in classroom management and planning of activities, because the everyday tasks are demanding enough. Their participation in this sort of communities have been discussed as helping them to overcome this teacher centred and immediate concerns (Thomas, Wineburg et al. 1998)

Similar differences are encountered between primary and secondary school teachers regarding cooperation and community (Bolam, McMahon et al. 2005). In secondary schools, where collaborative relationships are particularly hard to achieve in the face of

a historical legacy of top-down administration and fragmented departmentalized subject-based communities, school wide cooperation is especially difficult to establish and maintain (McLaughlin and Talbert 2001; Giles and Hargreaves 2006). Primary schools, on the contrary, can more easily show a quite interesting working culture of mutual support and cooperative learning (Nias, Southworth and Yeomans 1989).

Due to these important differences regarding the experience and type of teachers participation in collaborative settings or communities, it is sometimes necessary to "*level the playing field*" so that everyone has something to learn, or reflect on, or inquiry about within the collaboration. In this sense, the literature mentions that dealing with interdisciplinarity or innovative strategies can be good scenarios in which everyone has lack of expertise in certain aspects and expertise in others (Thomas, Wineburg et al. 1998). Another crucial aspect for teacher cooperation or communities to work for effective professional development is the role of researchers, which has been described as that of facilitators and consultants. In general, researchers organise the teacher development activities, bring resources and guide discussions. However, if teachers are expected to develop and the community has vocation of sustainability (becoming the normal working culture of the teachers and the institution), there has to be room for teachers' agency and strong promotion of teachers' leadership, in particular *sustainable leadership* (Hargreaves and Fink 2006). Balancing the offer of appropriate guiding with the support of teachers' autonomy becomes the crucial task of researchers, teacher leaders and teacher educators facilitating professional development cooperative scenarios.

The aspects related with teacher cooperation mentioned in this section refer mostly to the need for critical colleagueship instead of mere collegiality to become the school working culture, to be able to overcome the independent artisan metaphor. This has been discussed to be facilitated by managing cooperation and promoting collective involvement in change in, if possible, heterogeneous teacher groups (regarding expertise and subject matter specialisation). The reasons behind this claim for a focus on cooperation in professional development, however, are not just related to the need for professional development to be systemic at the institution level, as it could be inferred from the aforementioned argumentation. The main reason behind the interest on cooperation is related with the view of professional development as a social process, not only personal and professional one (Bell 1996, Bell and Gilbert 1998) which in turn is due to a socio-constructivist view of teacher learning and change. In

this sense, more about cooperation and its relation with teacher learning will be discussed in the following section on teachers' learning.

4.1.3.3 The role of the subject in effective professional development

A final aspect that is mentioned in the reviews of effective professional development is the importance for it to be centred on the subject. In the case of science, this has been stressed in the previous reviews of effective professional development with notions such as teachers being learners in the subject; teachers increasing their content or pedagogical content knowledge; teachers engaging in activities used with students in the science classroom (in-depth investigations, problem solving, inquiry and collaborative work for learning science), etc. As the authors point out, this implies placing content as central and integrated with pedagogical issues for the effective professional development of science teachers.

We already now that disciplines greatly matter in teaching (Stodolsky 1988), this being the standpoint of the Science Education research field. In this sense, they also should matter in teacher learning and development to teach. According to Schoenfeld (2004) "*the challenges and perhaps even the mechanisms of teaching for understanding in various content domains [are] shaped by the character of the disciplines being taught*" (p.237), because the disciplines themselves are ways of making sense of phenomena. As so, learning a discipline involves also learning prototypical or paradigmatic ways of sense-making, not only a body of domain specific knowledge (Schoenfeld 2004). However, the role of subject matter in studies of learning to teach has been missing for quite a long time, as Shulman (1986) strongly criticised in his influential works. Despite some interesting studies that followed Shulman's claims, most recent research and theory building in the general professional development field has not been driven by subject matter concerns, but by concerns about general professional growth and adult learning and development (Loucks-Horsley, Love et al. 2003).

According to Loucks-Horsley and Matsumoto (1999), research on teacher learning has underscored the need for professional development to help teachers understand (a) subject matter, (b) learners and learning, and (c) teaching methods. Despite research shows that the professional development initiatives that combine these three content goals provide teachers with what they need to teach their subject matter well, for the authors quite often professional development emphasises the second or third

domains, forgetting or taking for granted enough knowledge of subject matter and, more importantly, enough knowledge about how to teach the subject. In his works, Shulman (1986) addressed this problem (lack of focus on subject matter or just focus on the content of the subject, with independence of the teaching situation) by introducing the notion of *pedagogical content knowledge*[17] (PCK). This was defined as the especial kind of knowledge that is the providence of experience and expert teachers, which includes *"what concepts in a discipline are most appropriate for students of a certain age, how the students come to understand those concepts, what naive conceptions or misconceptions they are likely to have, and what representations, examples, and experiences help them learn"* (Loucks-Horsley and Matsumoto 1999). The concept of PCK establishes a necessary link between science and general pedagogy. According to Shulman (1987), PCK is *"the content, character, and sources for a knowledge base of teaching"* (p.4), and in this sense it has originated a fruitful research programme about what knowledge is essential to be able to teach (Fenstermacher 1994). Since its origin, PCK has become a central concept for the field of science education (also other specialist education fields), a *construct* with many implications for the field, and as such, for the professional development of science teachers (Gess-Newsome and Lederman 1999).

To master PCK means understanding major concepts of teaching and learning of a particular subject matter, but also knowing how to apply that knowledge to new and challenging situations, which is necessary in order to innovate subject matter teaching and change practice. As some authors pointed out, teachers' change do not happen in the abstract, but about concrete content (Gunstone and Northfield 1994; Mellado 2003). Even within paradigms that traditionally emphasised the importance of general aspects for teaching over subject matter, as the "teacher thinking" paradigm (Marcelo 1987), there has been an evolution towards an stronger focus on the subject (Marcelo 1993). In their review of the professional development field in science (and also mathematics) education, Loucks-Horsley and colleagues (2003) conclude that PCK should be the focus of professional development. In our context, many authors have also been claiming for the importance of a focus on the *didactics* of scientific content in both pre- and in-service teacher education (Furió and Gil 1989; Gil 1993; Furió 1994; Mellado 1995; Porlán 1998; Mellado 2000; Izquierdo-Aymerich 2005;2008)

[17] Due to the extensive use that the concept pedagogical content knowledge has in Science Education, we have referred to this concept before in our work. However, it is in this section that we define it and refer to its sources and history.

The importance of a focus on subject matter has been emphasised in the literature also regarding the particular approaches of the innovations and reforms that are being implemented in the science field nowadays. As mentioned in the introduction, the introduction of the approach of *Science for all;* demands for a more *Science, Technology and Society* (STS) contextualisation; the idea of *integrated science* for dealing with relevant problems that can not be addressed from the single scientific discipline; the notion of *Public Understanding of Science* related with citizens decision-making; or the highly demanding inquiry approach to teaching and learning scicence, among others, have been discussed as posing real problems regarding the mastering of subject matter, both content and pedagogical content knowledge, for most teachers. These approaches imply a *re-invigoration of the curriculum* (Lang, Drake et al. 2006), not just teaching the same in different, more effective ways. Aikenhead, for instance, discussed the new knowledge and way of knowing the specialist science teachers' need within STS approaches with emphasis in decision making (Aikenhead 1987). Lang and Olson discussed that for teaching *integrated science* teachers had to develop new conceptual structures (Lang and Olson 2000). In the context of a new curriculum on *Public Understanding of Science*, new science teachers' knowledge on models and modelling was needed too (Henze, van Driel and Verloop 2007). According to Barrow (2006), within the well-accepted view of *inquiry* as a central part of the content of the science subject, *"Science methods courses need to provide future science teachers with exemplary examples of inquiry as a content area"* (p.271), as teachers' lack this subject matter knowledge and, particularly, how to use it in the classroom. The list of examples of new approaches to science teaching that challenge the traditional subject matter and PCK knowledge of science teachers is almost endless.

The interest of a focus on subject matter regarding professional development of teachers has been largely called for, not only theoretically, but as a result of studies of professional development impact in classroom practice, that is, on students' results. Kennedy (1998b) reviewed a variety of in-service programs focusing on those that demonstrate evidence of improved student learning. His review showed that programmes focused on subject matter which help teachers learn how students learnt the subject matter were the most successful in improving student achievement. The same situation was found regarding mathematics professional development (Cohen and Hill 1998). This idea, that teachers' should learn in similar scenarios and ways than

those they are expected to create in the classroom for they students[18], is in agreement with results found in other reviews of teacher learning and professional development (Putnam and Borko 1997; Wilson and Berne 1999; Loucks-Horsley, Love et al. 2003). Kennedy stated that, by learning how students learn the subject matter, teachers also (a) learned the subject matter content themselves; (b) learned how to recognize if and how students are learning their subject; and (c) learned ways to teach the specific subject matter. All three are aspects of PCK, as stated before. In a large-scale quantitative study of characteristics of professional development initiatives with bigger impact in science and mathematics teachers' knowledge, skills and classroom practice, Garet and colleagues also found that the focus on content knowledge (together with opportunities for active learning and coherence of professional development with other learning activities) was the more significant factor (Garet, Porter, Desimone, Birman and Yoon 2001). In fact, it was through these core features that other structural ones such as the form of the activity, collective participation and duration of activity significantly affect teacher learning. A similar large-scale and quantitative study than that of Garet but in Australia found similar results: the authors noted a strong relationship between *content focus* on science and science teaching and reported impact on practice (Ingvarson, Meiers and Beavis 2005). All these results support the idea, also present in many reviews in the field (Kennedy 1998a; Hawley and Valli 1999), that a strong knowledge base and a clear theoretical rationale grounded in research are necessary conditions for effective programs. Supovitz and Turner (2000) also found empirical results regarding the importance of professional development focussed on scientific content and PCK. In their study, they found significant impact of "high quality" professional development, as described in the previous section, on science teachers' practices and classroom cultures (in their case, regarding the use of inquiry-oriented teaching). According to their results, *"the content preparation of teachers was by far the most powerful individual teacher factor"* (p. 976). In the sense that, regardless the extend of professional development, content preparation was the factor that showed a bigger statistical significance on teachers' change of practice. Despite the interest of these results, however, we need to urge caution to their direct validity for our work, because the importance that professional development focused on subject matter content has is strongly dependant on teachers' background, their pre-service training and the educational system of each country. In the Anglo-Saxon culture were most of these large-scale studies have been done (US and Australia), science

[18] This idea has deeper implications than the one intended here (highlighting the importance of subject matter also for teachers) that will be explored when dealing with teacher learning in following sections.

and mathematics teachers are conscious of their need for more subject matter learning, ranking the deepening of their content knowledge as their second choice of focus for professional development (Weiss, Banilower, McMahon and Smith 2001). In this sense, we do not know about results of research that show this sort of interest in learning subject matter from Spanish teachers, neither of large scale studies that rank the impact of professional development focused on subject matter. From the research point of view, however, despite the specialist background on science of Spanish teachers, the importance of keeping abreast regarding their subject and particularly learning pedagogical content knowledge of their subject, has also been emphasised in the Spanish context (Furió and Gil 1989; Gil 1991;1993; Furió 1994; Mellado 1995; Porlán and Rivero 1998; Mellado 2000; Izquierdo-Aymerich 2005)

The subject *matters* not only because its impact in teaching, but because its impact in who the teacher is (the social and professional identity of the specialist teacher) and thus, on teachers' culture. Especially in secondary and higher education, were teachers have a deep background in their subject, a teacher's professional identity formation is strongly determined by the subject he or she teaches (Sikes et al.,1991, cited in van Driel, Beijaard et al. 2001)[19]. It is known that secondary school teachers define themselves as subject specialists (Brandes and Seixas 1998). According to Helms (1998), science teachers *"construct an identity in direct relation to science"* (p.831). In this sense, they are socialized within their disciplines (Hansen 1999), belonging to distinctive subject-related subcultures: first, the Chemistry, Physics or Biology culture within the university; second, the culture of the science staff department and the science classroom within the school, which are characterized by differing beliefs, norms, and practices. These different beliefs, norms and practices are perceived by teachers' themselves as significantly influencing not only their experience of teaching science[20], but also their professional working environment (Donnelly 2000). In this sense, understanding subject specialist differences among high school teachers has been reported crucial for the analysis of reform (Grossman and Stodolsky 1995) because, according to the authors, shared beliefs about the possibilities and

[19] The original work of the authors is in German.

[20] In an empirical study comparing the educational aims of science teachers with those of teachers of history, Donnelly (2000) found that while science teachers "*place a stronger emphasis on established knowledge, commonly ground relevance in instrumentality, and perceive uncertainty as threatening"*, historians *"try to place children's interpretations and intellectual judgements at the centre of their work"* (p.17). According to the author, this is related with the intellectual orientation of each discipline, which had strong implications on teachers' aims.

constraints posed by different school subjects may complicate efforts to restructure schools or redesign curriculum. Because the dynamics of policy implementation and effect may reflect the dynamics of particular subject-matter cultures, they have been argued to be a central feature of practice and reform alike (Knapp 1997). As a consequence, teacher subject-matter identity and culture are also crucial for the design of the professional development needed to support these reform efforts. However, the influence of teachers' subject matter in teacher identity and culture is quite often neglected in studies of teachers and teaching (Grossman and Stodolsky 1995; Helms 1998).

In the case of science, some authors have pointed out that the culture of traditional "school science" may restrict the professional development of science teachers (Munby, Cunningham and Lock 2000). This is related with teachers' epistemological beliefs of science and *school science*[21]. The authors refer to the fact that science in the classroom is usually presented as *"a rigid body of facts, theories, and rules to be memorized and practiced"* (van Driel, Beijaard et al. 2001). This dogmatic and empiricist view of the discipline has shown to be widely shared by teachers (Lederman 1992) and has been discussed to influence dangerously teachers' teaching models (Millar 1989; McComas 1998). Despite some studies (Mellado 1997; Abd-El-Khalick, Bell and Lederman 1998; Mellado 1998; Lederman 1999; Southerland, Gess-Newsome and Johnston 2003) have shown that the correspondences between teachers' epistemological views of the nature of science and their actual teaching practice are more complicated than originally assumed, researchers and educators do not dispute the importance of teachers' changing their views of science towards more appropriate ones (Abd-El-Khalick and Lederman 2000; Tsai 2006). In this sense, McComas and

[21] *School science* is often referred to in the literature with very different meanings. While some authors refer to it as if it was a *simplified* science or the subset of science content that is dealt with in school, other authors have done an important work in characterising its particular features (Sanmartí and Izquierdo-Aymerich 1997; Izquierdo-Aymerich, Espinet, García, Pujol and Sanmartí 1999; Izquierdo-Aymerich, Sanmartí and Espinet 1999) and theorising (Izquierdo-Aymerich 2005) about *school science*, discussing its epistemological foundations (Izquierdo-Aymerich and Adúriz-Bravo 2003) as a science *on its own* that is connected with (but it's not the same as or just part of) scientists' science. We share this latter view of *school science*, which emphasises the importance of the concept of Didactical Transposition (Chevallard 1991) in Science Education. However, along this work, we refer to *school science* with a more loose meaning when quoting other authors.

Olson (1998) noted an emerging consensus towards a constructivist view[22] of the nature of science, according to official standards, which has influenced *school science* to become more contextual and social. Despite the importance of this shift, Izquierdo-Aymerich and Adúriz-Bravo (2003) urge caution to the fact that *"radical socio-constructivism derived from it has proved to be dangerous because of its sceptical and relativistic conception of knowledge, which is unsuitable for school science"* (p.28). According to the authors, then, an overemphasis on context (for instance just focusing on the effect of the social milieu or discussion in science) fails to recognise the intrinsic importance of scientific concepts and their connection to natural phenomena within the science classroom, and has then important consequences for the teaching of science. Therefore, it is necessary to balance both cognitive and social aspects in constructing a sound image of science[23] for education. The need for this balance is also important to be taken into account regarding professional development for the science teachers, not only for their possible influence in the classroom (not direct, as mentioned) but also for their influence in teachers' identify and culture. As Helms (1998) states when referring to science teachers' struggles to define their own view of science, that effort "*was not simply a philosophical exercise, but an attempt to understand more about themselves, to gain a richer understanding of who they are, why they do what they do, and, I argue, who they want to become"* (p.831).

[22] The constructivist view of the nature of Science emphasizes the tentative nature of science knowledge, the theory-laden quality of scientific exploration, the role of evolution in progressive development of scientific understanding and the social, historical and contextual influences in the enterprise of science (McComas and Olson 1998)

[23] Izquierdo-Aymerich and Adúriz-Bravo propose a new model of science which is appropriate also for *school science*, because it shares its cognitive goal and is adapted to the *cognitive* context of the classroom. This is the *cognitive model of science* based on the works of Ronald Giere (Giere 1988;1992). Ronald Giere, from contemporary philosophy of Science *"portrays science as a human enterprise whose aim is to interpret the world by using human capacities of thinking theoretically and progressing towards a goal" (*p.29). The cognitive model of science, then, *"focuses on how scientists work and communicate (especially through writing), and highlights the semantic aspect of theories: their goal is not to reach truth but to make sense of the world, according to the ultimate objective of an active transformation of nature (Hacking, 1983). In this process of giving meaning, cognitive and social factors have a key role (Nersessian, 1992)."* (p.31, in Izquierdo-Aymerich and Adúriz-Bravo 2003). For the authors, despite scientists' science and school science are different, it is possible that science teaching could be similar to the construction of science if it is accepted that *"trying to explain the world theoretically is the most important characteristic of Science, <u>and</u> also the major objective for school Science."* (p.36, emphasis in the original).

Following the relation between teachers' epistemological beliefs of the subject and their identity, Hansen (1999) has argued that when teachers' disciplinary socialization in science plays a bigger role than a pedagogical or didactical socialization on science teaching, problems and scepticism could easily arise regarding reforms and innovative rationales that foster deep changes in the subject (Black and Atkin 1996). For the author, the aforementioned reforms (*Science for all, STS, integrated science,* etc.) do not only pose problems of knowledge of subject matter to teachers, but problems of identity and socialization: they challenge teachers' primary socialization in the discipline (Hansen 1999). These sorts of innovations, according to the author, demand a different professional identity, more based on didactics and pedagogy *"than the esteem typically assigned to the pure science disciplines and through which most teachers are socialized"* (p.141). In this sense, *new* professional development initiatives to support these approaches to science teaching should have into account if the teacher socialization in the single or traditional subject shows problematic, and offer opportunities for the teachers to socialize in an extended professional culture. In the same way as Aikenhead (1996) refers to the *"typical science classroom as a cross-cultural event for many students"* (p.1), the non-typical one, the one that brings science closer to the students' culture (the world of the learner), that is highly contextualised and makes explicit the borders to cross from everyday experience to science phenomena, within an appropriate, constructivist and cognitive view of the nature of science, can be seen also as a cross-cultural event for many science teachers. In other words: teaching *a different science* in a *different science classroom*, that is, teaching a different curriculum with a different approach and epistemological rationale implies being a *different science teacher.* In this sense, science teachers' can benefit from certain interdisciplinary teaming with subject specialists of different science disciplines when addressing general aspects of teaching and learning of science, so that science teachers socialized also in the science teaching culture in addition to their own discipline culture. The same applies to teaming with other specialists outside the science field.

The importance of the subject on professional development appears, then, clear for the different reasons discussed above. Fortunately, the new professional development is already taking this into account and the characteristics of the discipline (in this case science) "*directly correspond to the new directions professional development is taking"* (p.XIX, Loucks-Horsley, Love et al. 2003). According to the authors, some of the key principles of the identified paradigm shift in the professional development field (*"from transmission of knowledge to experiential learning, from reliance on existing research*

findings to examining one's own teaching practice, from individual-focused to collaborative, and from mimicking best practices to problem-focused learning") are actually the most important principles behind recent reforms in science and mathematics education. In this sense, the *new* professional development "mirrors" the *new* views of the subject and the subject teaching in current reforms and give the importance it deserves to the subject. However, as Shulman himself points out when presenting a shifted perspective regarding teachers' learning from his previous works, the new professional development scenarios designed to support and foster reform challenge a focus *only on subject*. For the author, *"while 'the subject matters' in these settings, there is so much more going on simultaneously that at times the ever-important content differences can be swamped by other critical features of the context"* (p.269, Shulman and Shulman 2004). In this sense, subject plays a role that can not be neglected, but also do context, cooperation and community, and the inquiry culture aforementioned.

To sum up, according to all the above mentioned what the literature points out as effective professional development scenarios are scenarios where teachers have an inquiry/reflective stance towards practice, within a cooperative culture of critical colleagueship and with an important focus on the teaching and learning of their subject. These ideas have been found to come from very different studies, being an almost general consensus in the literature about them as being important characteristics of effective professional development. However, there are strong differences among these studies regarding the sort of evidences they rely on when discussing effectiveness of teacher professional development. In this sense, the following section is devoted to this complex topic

4.1.3.4 Effectiveness of professional development

Nowadays, nobody would argue the existence of a link between teachers' development and students' outcomes. As mentioned at the beginning of this work, there is broad consensus, not only in educational research but also in educational policy, regarding the view of "teacher quality" as the single most important school variable influencing student achievement. The connection, however, between particular professional development initiatives and students' learning is less clear. As some authors have pointed out, research on or evaluation of professional development usually does not assess students' learning (Loucks-Horsley and Matsumoto 1999; Cochran-Smith 2000; Guskey 2000; Loucks-Horsley, Love et al. 2003). Instead, studies define effectiveness as different kinds of teacher engagement (attendance, continuity,

participation,...); perception of learning or, at best, teacher change in knowledge or classroom practice (Loucks-Horsley and Matsumoto 1999). In this sense, the importance of appropriate evaluation of professional development has been largely discussed in the mentioned literature and also in policy documents and reports (NCTAF 1996; OECD 2005).

Guskey (2000) elaborates a little bit more on the three major mistakes found in past evaluations of professional development that made them inadequate and ineffective. First, quite often professional development is not evaluated at all, and what is offered is just an account of the activities that took place, without further analysis. Second, as mentioned, in most cases these evaluations are "too shallow". According to the author, *"those responsible for planning professional development often are satisfied if participants enjoy the experience. As long as educators who attended regard their time to be well spent, the effort is considered a success"* (p.9). In some cases evaluations are extended to consider the effects on teachers' perceptions, attitudes, or beliefs. Despite the importance of these, it would be interesting to have also other important indicators of success, such as real assessment of participants' professional knowledge and better accounts of change in practice, despite the ethical concerns and methodological difficulties of doing so. However, the most problematic issue is the fact that *"rarer still is any consideration of the impact on students"* (p.9), which is the main goal of these professional development initiatives. Third, evaluative efforts are too brief. To document large-scale and long-term effects, evaluations must be extended over longer periods of time. *"The problem, of course, is that we often rush to provide evidence on effectiveness and expect too much too soon"* (p.9, Guskey 2000). In this sense the author, in agreement with others, have claimed that "*to be truly useful, evaluations must probe deeper".*

To be able to assess the efficacy of professional development, it has been argued we need better information about the effects of professional development at various levels, including the teacher, the system and the students, together with the conditions and processes that lead to success, as well as information about possible unanticipated outcomes (Guskey 2000). This claim for a more systematic measure of impact is also present in Loucks-Horsley and colleagues' review of their influential model for the design of professional development in Science and mathematics presented in 1998, in which the authors change the feedback process from *reflection* to *evaluation*, signalling *"the critical importance of rigorous evaluation of professional development both to inform redesign and to document the impact on student learning,*

teacher learning, teaching practice and organisations" (p.1, Loucks-Horsley, Love et al. 2003)

The above mentioned and other authors have stressed the fact that designers of professional development opportunities should clearly connect professional development to students' learning, establishing a *tighter link* among the two. Despite students' outcomes are well-accepted as the focus of professional development (that is, the focus of teachers' reflections and inquiries and the main source of evidence for guiding this process), it is much more controversial the measurement of students' learning for measuring the impact of professional development. Some authors argue that the fact that there is very little research addressing directly the connection of professional development and students' learning outcomes it is due to the difficulty in establishing a clear connection between the two (Loucks-Horsley and Matsumoto 1999). In the following, we will discuss this issue a little bit.

In general, the studies on the impact of teachers' development in student's results have a small scale and narrow focus, being of interest the concrete particularities of an innovation (a particular teaching strategy, a particular PCK, etc.) that are expected to have an impact in students' outcomes. In this sense, quite often the evaluation is at the same time an evaluation of the innovation, the materials used and the professional development scenario designed for the teachers' participating in the innovation. In these sorts of studies it is used real data from students, generally results of tests which have been purposefully designed for analysing the impact of the particular focus of the innovative materials or teaching strategies used. What it is measured is not improvements in students' general scientific literacy, but only regarding the concrete aspects dealt with. In this sense, the results can not evaluate impact of the professional development *alone* neither regarding students' learning *in general*, as sometimes seem to be assumed. On the other hand, when large-scale programmes measuring impact on students have been used, these generally have based their results in teachers' reports, and thus perceptions of students' results, rather than actual students' learning outcomes (Garet, Porter et al. 2001; Ingvarson, Meiers et al. 2005). This is mainly because either there are no external tests available that *fit with* (and thus evaluate with validity) the professional development goals or because when these general and external tests exist, the scope of the professional development initiatives is not big enough to apply them and compare with other students, if this comparison (with all the other variables affecting) is even possible.

All these methodological constraints to establish a clear link between professional development and students' outcomes are common in other areas of the educational field, because they are product of the intrinsic complexity of the learning process. As Loucks-Horsley and Matsumoto (1999) pointed out, it is very difficult to establish clear links between professional development and student learning because many different aspects influence the latter. The authors referred to the Guskey and Sparks (1996) model of the "sphere of influence" on student learning according to which students' outcomes are improved through the complex relationships among quality professional development and administrators', teachers', and parents' knowledge and practices and a number of other factors influencing each of these components. These authors concluded that *"establishing a clear link between professional development and improved student learning- if one actually can be made- requires substantial research and evaluation that carefully account for the various contributions that each factor makes to the desired outcome".*

Despite the above mentioned setting limitations to the measurement of student learning when evaluating the impact of teachers' professional development, the review of Loucks-Horsley and Matsumoto (1999) showed that *"the findings of studies that examine student learning* [within the constraints just mentioned] *are similar to those that do not, suggesting an emerging consensus*" regarding efficient professional development. This consensus is also in agreement with teachers' perceptions of impact on their knowledge, beliefs and practice regarding certain professional development designs in the science field, even from large-scale studies (Supovitz and Turner 2000; Garet, Porter et al. 2001; Weiss, Banilower et al. 2001). In this sense, despite the problems of evaluating impact already mentioned, we consider that the emerging consensus in the literature regarding effective professional development, the one displayed in Table 2, is also result of a variety of measures of effectiveness and not only of theoretical reflections in the field.

4.1.3.5 Effective professional development in our publications

In the previous sections in has been discussed that, whatever the model, particular design or combination of designs of professional development, effective professional development is long-term and systemic, and characterised by three features: promoting a reflective or inquiry stance, being collaborative in an atmosphere of critical colleagueship and focused on subject-matter (See Table 2). Again, the three publications that form part of this compendium share these characteristics, being the

main focus of each of them one of the mentioned singular features of effective professional development.

Publication 1, as has been mentioned, is strongly focused on subject-matter. The selection of the particular scientific content addressed is based on a previous research regarding the difficulty of teachers to use a particular *didactical transposition* of the energy concept, which is also part of the published paper included in this work. This didactical transposition introduces the idea of energy degradation together with the idea of energy conservation, which the literature in the field have largely discussed as useful to avoid common students' misconceptions (see literature review of Publication 1). The structured way of dealing with subject matter learning proposed in the paper, based on constructivist views for a teacher education workshop, is justified by the importance of the topic and its difficulty for both teachers and students in different contexts. Despite the emphasis in the paper relies on clarification and learning of scientific content and pedagogical content knowledge, the other two characteristics of effective professional development are also taken into account. The professional development workshop proposed relies on teacher collaboration and reflection on practice as its main strategies for teacher learning.

Publication 2, on the contrary, has no focus on subject-matter. Being designed as a setting for teachers' collaborative reflections about their process of participating in school-based innovations, the content of their discussions refer to aspects of the profession, the school organisation and the wider social and political context in which teachers were trying to participate in innovation and reform, rather than to issues of teaching and learning in the science classroom. This situation was purposefully planned by selecting teachers who were participating in a variety of educational change scenarios instead of teachers putting into practice the same type of innovation. The idea was to allow critical reflection on the *meta-level*, that level difficult to achieve in the school setting where teachers discuss issues related to their everyday practice. The goal was to capture the teachers' voice in school-based reform, which is related with the emancipatory role of reflection discussed in the literature. In this sense, the most important feature of this scenario, which we discuss as an interesting setting for professional development of certain aspects, is the focus on reflection.

Reflection here is promoted at the individual level before the activity, with the use of teacher narratives as a personal account of the process of participating in the innovation. During the setting, a series of activities to foster collaborative reflection

were proposed (See details in Publication 2). Collaborative reflection, as was discussed in previous sections, is a more powerful scenario than individual reflection alone, allowing the sharing of different points of view (Zeichner 1994). According to teachers' comments in the final feedback questionnaire, the activities done to foster collaborative reflection were considered useful, and some teachers decided to use a methodology inspired in this particular setting for their staff meetings at school. Interestingly, the goal of the series of meetings and on-line exchange was the preparation of a final document as an outcome of the collaborative reflective work, which teachers revised afterwards. An evidence of success of the initiative is the fact that the final goal was accomplished, teachers showing ownership of this final document that summarises their discourse along the professional development setting. Despite we can not say that the participation of teachers in this brief series of events implies that teachers dramatically changed their view of their professional practice and became more empowered and able to reflect, understand and even play better the extended roles demanded in school-based innovation, we have evidence that for some teachers' this was the first time they were involved in this sort of critical reflections at the meta-level which they reported to truly interest them.

Finally, in Publication 3 both subject matter and reflection play a role. When analysing teachers' discourse during their activity of designing innovative curriculum materials for the science classroom, this discourse is situated quite a lot in the scientific area (discourse on science) and also part of it is classified as reflective or meta-cognitive. Regarding the former, science is an important content of teachers' discourse, particularly within certain curriculum design activities and cooperative contexts. It is in this sense that the analysis of teachers' discourse done, in which certain patterns of discourse focused on subject matter are found, shows interesting. Regarding the latter, meta-cognitive and reflective discourse as defined in Publication 2 it is not reflective regarding teaching and what happens in the classroom, but regarding curriculum design and what happens in the teachers' group. In this sense, it is a discourse by which teachers analyse evidence on their practice of curriculum design to manage and better understand it, to make decisions. As such, it is a parallel discourse of that expected from expert teachers regarding what happens in the classroom, but regarding what happens outside it in bottom-up innovation scenarios. This does not mean that teachers, when analysing the testing of their materials, do not reflect at the classroom

and students level[24]. However, it is interesting that the sort of professional development initiative these teachers self-organise and participate in, also shows reflection regarding extended parts of teacher professionalism. This is reflection of teachers as curriculum makers, which is an interesting scenario for teachers' professional development (Parke and Coble 1997).

In addition to addressing subject matter and reflection, Publication 3 is particularly focused on teachers' collaboration. The very essence of the setting analysed is collaborative, with teachers' working together, sharing professional knowledge, beliefs and practices, but also personal experiences and feelings. As it is described in the paper, the group is strongly cohesive, a comfortable and productive exchanging and working place for teachers, as shows the fact that they attend voluntarily and for an extended period of time. There is no mere collegiality here, but strong cooperation addressed to the accomplishment of a particular goal: the design of innovative curriculum materials for science teaching. This implies collaborative learning, collaborative reflection and collaborative inquiry. In this sense, collaboration is what makes this setting what it is, and gives it the potential to be considered an interesting scenario for professional development. In fact, the sort of collaborative scenario of Publication 3 is more related with the ideas of teachers' community[25] (community of practice, learning community, etc.), than just collaboration. This is because there is evidence on teachers' cooperative discourse and practice of teachers' commitment; shared norms, values, meaning and goals; interest in each others' learning and development, etc.

According to what is mentioned, all three publications share some aspects of effective professional development, that is, a focus on subject-matter (except Publication 2), on reflection and inquiry on practice within or outside the classroom, and on collaboration, either as cooperative work or forming community. However, each of them is more focused in one of these features than the others (see Figure 4): Publication 1 on subject matter; Publication 2 on reflection and Publication 3 on

[24] The meetings analysed here belong to the initial stage of the group work of designing curriculum materials, so there is no evidence of such discourse in the data reported here. However, after designing it, teachers tested their materials in the classroom, and despite their focus was not that of doing practitioner research on students' results, they revised their materials in an evidence-based manner.

[25] The particular characteristics of teachers' community, in particular the notions of communities of practice, learning communities and professional learning communities, due to the fact that have an strong impact in teachers' learning, will be explained in the next section on teacher learning.

collaboration. In this sense, the compendium of publications refer to initiatives that cover the spectrum of effective features for professional development, allowing the exploring in detail of each of these single but related aspects in each of them.

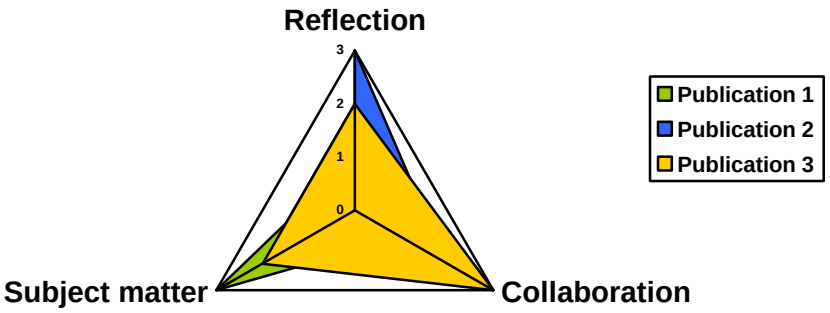


Figure 4: Representation of the main features of effective professional development focused on in Publications 1, 2 and 3 of this study.

4. 2 Teacher learning

> "Put more simply, successful change involved learning how to do something new. As such, the process of implementation is essentially a learning process" (p.1)
>
> M. Fullan and A. Hargreaves (1992)
> *Teacher development and Educational Change.*

> " […] even for the teacher, learning is not easy" (p.64)
> C. Furió and J. Carnicer (2002)
> *El Desarrollo Profesional del Profesor de Ciencias Mediante Tutorías de Grupos Cooperativos.* Enseñanza de las Ciencias.

According to Cochran-Smith, the future of professional development implies framing the questions that matter. For the author, these are the knowledge question, the learning question, and the outcomes question (Cochran-Smith 2000). When focused on the teacher, this means asking what teachers need to know, how would they learn it and what would be the effect of learning that on their practice. In this sense, the main questions regarding professional development can be framed around questions on teacher learning: what to learn, how to learn it, and why.

As a field, we know very little about what teachers learn within their work place and the multiple professional development opportunities in which they participate (Wilson and Berne 1999). According to the authors, one of the problems is *the "scattered and serendipitous"* nature of teachers' learning. Teacher professional learning occurs in many different aspects of practice, including their classrooms, their school, and, of course, in professional development activities (Bransford, Brown and Cocking 1999; Borko 2004). This poses a problem to the research in the field because *"to understand teacher learning, we must study it within these multiple contexts, taking into account both the individual teacher-learners and the social systems in which they are participants"* (p.4*,* Borko 2004*).* Despite some research exist, generally in the form of rich case studies which provide important information about the changing practices of teachers, there is general agreement in the field regarding lack of sufficient data on teachers' learning.

In spite of this, when dealing with professional development we need some knowledge about how teachers learn. What we know of teacher learning is one of the principal knowledge bases and beliefs used to support professional development

(Loucks-Horsley, Love et al. 2003), together with views of teaching, the subject and educational change. According to the authors, this knowledge is necessary at least at two levels. First, teachers need to have learning experiences that *"help them understand how children best learn"*, for instance science, so that they become more able to provide such experiences to their students. Second, professional development designs offered to teachers should be product of a reflection on how people learn so that these adult learners are also *"supported to learn in a sustained and in-depth way"* (p.33). Whatever the view on teachers' learning, either formal and theoretical or informal and unconscious, this view is in fact embedded in the design of professional development. In the same way that teachers' view of learning influences how they teach and the learning scenarios they provide to students, researchers' and teacher educators' view of teacher learning greatly influence their design of professional development activities and scenarios. For most authors, the problem is that quite often the view of teacher learning that guides professional development, in particular in its traditional form, have no relation with our knowledge about how people learn (Ball and Cohen 1999; Cochran-Smith and Lytle 1999; Putnam and Borko 2000). The authors follow the general assumption that *"what is known about learning applies to teachers as well as to their students"* (Bransford, Brown et al. 1999), and, in this sense, the knowledge we have about how people learn should be taken into account.

4.2.1. How teachers' learn?

We know a great deal about how people learn. *"An explosion of cognitive research in the past 20 years has resulted in a rich body of knowledge about learners and learning in general and in Mathematics and Science in particular"* (p.6, Bransford, Brown et al. 1999). However, for Loucks-Horsley and other authors (Loucks-Horsley, Love et al. 2003), too often this cognitive research is forgotten when it comes to teachers' or other adults learning.

According to the authors five[26] general principles summarize what we need to know about learning regarding teachers, which is inspired in what we know about learning for

[26] We work here on four instead of five principles because the last one, *"All students are capable of understanding and doing science"*, despite very useful when designing professional development, is not relevant here when analysing teachers' learning.

any learner as stated in the influential work of Bransford and colleagues (Bransford, Brown et al. 1999):

- What learners already know influences their learning
- Learners acquire new knowledge by constructing it for themselves
- The construction of knowledge is a process of change (addition, creation, modification, refinement, restructuring, rejection)
- Learning happens through diverse experiences

Today it is widely accepted that what learners know is an important foundation for their future learning, that quite often existing conceptions are inconsistent with accepted knowledge (in science, the students' alternative frameworks gathered by Pfundt and Duit (1994) are the most well-known example) and that these alternative conceptions are tenacious and resistant to change, because the existing ideas interact with and even filter the new knowledge, making difficult the necessary building or modifying of them (Wandersee, Mintzes and Novak 1994). We know also that learning is not only influenced by what we already know, but also by our emotions, such as expectations and attitudes towards learning and view of oneself as learner. In this scenario, that of a certain *constructivist consensus* (Novak 1988; Gil, Carrascosa Alís, Dumas-Carré, Furió, Gallego Badillo, Gené, González, Guisasola, Martínez Torregrosa, Pessoa de Carvalho, Salinas, Tricárico and Valdés 1999), constructivism has provided us with a theory of what learning is: a process through which learners actively construct their knowledge by modifying (sometimes rejecting) existing ideas. Or in other words: a personal and active process through which the learner interacts with information and experiences and filters them through what they already know (Bruner 1966).

What does this constructivist view of learning, and thus also of teacher learning, say regarding the design of professional development activities and settings? First, teachers need to be considered active learners, rather than the passive receivers they generally are expected to be in traditional forms of teacher training. Second, what teachers already know, do and belief (their actual knowledge, practice and attitudes) need to be taken into account both by teachers' themselves (the aforementioned idea of *reflective practitioner* of Schön) and in professional development desing. Many authors have criticize in-service courses presenting a new strategy or pedagogical content knowledge without taking into account what teachers knew and were doing

before regarding that topic. Third, perhaps the most important, teachers will not change their ideas and views if what is offered to them has not proven to be better than what they think or do at the moment. This gives importance to research-based professional development, that is, professional development that uses directly results from research with teachers so that they have evidence regarding the new theories and strategies that justify the attempt to change. More important even is the earlier discussed model of evidence-based professional development that involved teachers' themselves in this gathering of evidence (Harrison, Hofstein et al. 2008). Particularly in this latter case, when teachers' inquire their own practice and analyse the results of the new strategies or theories in their actual classroom, teacher *didactical change* (Tobin and Espinet 1989; Furió and Carnicer 2002; Mellado 2003), an idea parallel to conceptual change regarding conceptions of teaching, is more likely to happen. We will come to these notions in the following, when dealing with teacher change.

The influential previous ideas of constructivism view learning as a private, internal, and individual process. Egenström (1994) points out this fact, referring to it as the *individualist and Cartesian bias*, highly influential also in the important body of research on teacher thinking (Clark and Peterson 1986; Calderhead 1987; Marcelo 1987). According to the author, the literature in this field speaks of the teacher as *"an individual [instead of collaborative] thinker and actor"* (p.44). Since the 80's, however, one can find in the literature support for the idea of learning mediated by the culture and the social environment in which the learners interact. Influenced by the works of Vygotsky, a growing recognition of the role of the social and cultural aspects in learning has permeated the literature regarding science learning in the classroom (Solomon 1987; Tobin 1990; Driver, Asoko, Leach, Mortimer and Scott 1994) and for teachers (Engeström 1994; Bell and Gilbert 1996). This so-called *socio-constructivist* view of learning stresses the importance of interaction (and the mediation tools for this interaction, such as language) in learning. For Vygostky and followers cognition, and thus learning, has a social origin and nature: it appears first in a social plane, inter-psicologically, before becoming intra-psychological (Wertsch 1988). Linked with this socio-constructivist paradigm, *situated cognition* theories have also highly influenced the science education field. Within this framework, *"learning is a process of enculturation or individual participation in socially organised practices, through which specialised local knowledge, rituals, practices and vocabulary are developed"* (p.2, Hennessy 1993). In other words, knowing is a matter of active engagement in the world, of participation in the pursued of valued enterprises. Acquiring knowledge, that is

learning, is then viewed as social participation, a matter of being an active participant in the practice of a particular social community (Wenger 1998)

In a social theory of learning, then, learning is considered both social and situated. On the one hand, this means that we learn from others, with others, in our mutual interaction. This fact gives collegiality and cooperation a crucial importance regarding teachers' learning, far beyond the traditional calls for collegiality for organisational purposes. The well-know teacher isolation (Lortie 1975; Haberman 1992; Perrenoud 1995) is, then, not problematic only in institutional or emotional terms, but problematic for teacher learning. On the other hand, learning (cognition) is situated: it happens in the situations or in the social activities in which we are involved. In the case of teachers, it happens while teaching, while discussing with colleagues, while mentoring, while participating in action research. This is in agreement with the mentioned *extended* notions of *new* professional development. Important to this notion is the fact that because learning is seen as an integral aspect of activity, *"That learning occurs is not problematic"* but *"what is learned is always complexly problematic."* (p.8, Lave 1996). In this sense, fostering learning for teachers within the *situated cognition* framework implies supporting appropriate situations or activities in which teachers learn appropriate things.

The "rediscovered"[27] socio-cultural and situative perspective of learning described above have deeply permeated the recent literature of professional development, in which *"terms like "situated cognition", "distributed cognition", and "communities of practice" fill the air*" (p.11, Putnam and Borko 2000). For the authors, this represents a fundamental paradigm shift comparable with the now-historical one from behaviourist to cognitive views of learning.

According to Putman and Borko (2000b), three conceptual themes are central to this *situative* perspective of teachers' learning. These themes are to consider cognition as:

- situated in particular physical and social contexts
- social in nature
- distributed across the individual, other persons, and tools

[27] Despite this view are discussed to be "recent arrivals in the education field", in fact they have roots in the thinking of educators and psychologists from the nineteenth and twentieth century, such as Dewey and Vygotsky.

These ideas are interestingly fuelling current reform movements in education. For instance, regarding students', many innovations in the science classroom have been oriented towards fostering peer learning through cooperation, situating students' learning in meaningful contexts and giving extreme importance to the mediation artifacts, particularly language[28], and how the teacher-student or student-student interaction occurs. Now, even though with less attention, this *"situative perspective"* is being used also regarding teachers. On the one hand, teaching teachers this perspective as an approach they have to grasp in order to promote it in the classroom. On the other, more important for us here, using this approach for supporting teachers to learn and develop professionally.

This social theory of learning, when applied to teachers, challenges the traditional assumptions that, unfortunately, form part of the hidden rationale of many professional development activities and settings. These old assumptions are *"that learning is an individual process, that it has a beginning and an end, that it is best separated from the rest of our activities, and that is the result of teaching"*. (p.3, Wenger 1998) These assumptions are behind any individually-scoped, short-term, out-of-school, de-contextualised training in-service course. The new proposals of professional development based on a social theory of learning, on the contrary, give crucial importance to cooperation and context. Because learning is embedded in social practice and contextualised, *new* social practices in the appropriate contexts have to be promoted in order to achieve change.

[28] The importance of language in the Science classroom, following the well-known work of Jay Lemke (Lemke 1997), has not stopped growing recognition and has shown to be a powerful research focus. The analysis of the Science Education field by Peter Fensham concludes, in this sense, that language in the Science classroom is the new frontier that the mature field of Science Education is addressing now. In our context, there has been an important work on language in Science Education by different authors such as García, Jorba, Izquierdo, Marbà, Márquez, Roca, Sanmartí, Sardà and colleagues, which have mainly focused on reading, writing, argumentation, questioning and multimodal language (Jorba, Gómez and Prat 1998; Sanmartí, Izquierdo and García 1999; Sardà and Sanmartí 2000; Izquierdo-Aymerich, Márquez and Espinet 2003; Sanmartí, Calvet, Custodio, Estanya, Franco, García, Izquierdo, Màrquez, Oliveras, Ribas, Roca, Sardà, Solsona and Via 2003; Roca 2005; Márquez and Roca 2006). In this sense, language for science teachers' does not have the only connotation referred to here, as a mediator of their learning, but also as a mediator of their students' learning of science.

The notion of professional community that we will explore in the following section emerges in education as the possible scenario of a particular, learning-oriented, social practice and context for teachers.

4.2.2. Learning in community

> "The analysis of teacher learning in our efforts has moved from a concern with individual teachers and their learning to a conception of teachers learning and developing within a broader context of community, institution, polity, and profession" (p.267-269)
>
> L. S. Shulman and J.H. Shulman (2004)
> *How and what teachers learn: a shifting perspective*

Professional communities have been referred to as strategic sites for teacher professional learning, some authors stating that *"enabling professional growth is, at root, enabling professional community"* (p.31, McLaughlin 1994). This gives to this rationale an extreme importance. During this section, we want to discuss why communities are interesting for fostering teacher learning, in particular the sort of learning that allows school change and bottom-up reform.

According to Shulman and Shulman (2004), the features of accomplished teacher development, and thus the goals of teacher learning, are: *Vision, Motivation, Understanding, Practice, Reflection*, and *Community*. In their model[29], teacher development can be analysed at an individual level according to the first 5 characteristics but this individual development always occurs within a community that can enhance, actively inhibit or be neutral regarding the individual development of teachers. It is in this sense that the notion of teacher or school community is important, because it exits whether it is acted upon or not, and have important consequences for teachers' learning and development within their workplace. For instance, for teachers' to be successful in constructing their new roles in education and changing their practice, they need opportunities to participate *"in a professional community that*

[29] According to the authors, an accomplished teacher *"is a member of a professional community who is ready, willing, and able to teach and to learn from his or her teaching experiences*" (p. 259). Thus, the elements of the theory are: Ready (*possessing vision*), Willing (*having motivation*), Able (both *knowing and being able 'to do'*), Reflective (*learning from experience*), and Communal (*acting as a member of a professional community*).

discusses new teacher materials and strategies and that supports the risk taking and struggle entailed in transforming practice" (McLaughlin and Talbert 1993, p.15). This scenario will produce much more learning and development that that of a school where teachers implement a ready-made curriculum on their own without judging its quality or where they have to show expertise and good results whatever the case. Despite individuals contribute to the formation of the community norms, incentives, and practices; we have to take into account that, on its way back, the community exercises its influences on the participating individuals.

How should these teacher communities be in order to foster teacher professional learning (in particular, learning able to transform teachers' classroom practice and role within the school)? According to Fullan (1992) an interesting notion is that of fostering *interactive professionalism*. This means the support of teachers as continuous learners in a community of interactive professionals. The author describes this sort of settings as *"teachers and others working in small groups interacting frequently in the course of planning, testing new ideas, attempting to solve different problems, assessing effectiveness, and so on. It is interactive in the sense that giving and receiving advice and help would be the natural order of things"* (p.120-121). In the literature, this idea has been developed and referred to within different frameworks: *communities of practice* (Palincsar, Magnusson, Marano, Ford and Brown 1998; Wenger 1998; Putnam and Borko 2000; Little 2002); *discourse communities* (Engeström 1994; Putnam and Borko 2000); *teacher communities* (Thomas, Wineburg et al. 1998; Grossman, Wineburg et al. 2001) and the particularly important *professional learning communities* (Stoll, Bolam, McMahon and Wallace 2006; Hargreaves 2007; Stoll and Louis 2007), among others: on-line communities, networks (Lieberman and Grolnick 1996), etc. In common to all these "community" frameworks is that they focus on the idea of community as an ongoing venue for teacher learning (and sometimes also school change).

Seeing the diversity of notions and proposals, it is not surprising that some authors have *"urge caution about the profligate uses of the term community"* (p.6), which seems at risk of losing its meaning (Grossman, Wineburg et al. 2000). In this sense, we find important to elaborate more on these proposals, particularly in the too that deserve special attention. These are the framework of *communities of practice* and the notion of *professional learning communities*. Despite the similarities and interest for teacher learning of both, the former emerges as a social theory of learning, while the latter is inspired in ideas of teacher and school agency in educational reform. Because of this,

we find relating both models interesting: while the former gives a theoretical justification of why these communities are good learning places, the latter justifies why these communities are also good scenarios for teacher change in bottom-up reform.

4.2.2. 1. Communities of practice

The notion of communities of practice emerges from the social theory of learning explained earlier in this section. In this theory, learning is a matter of participation in the world. The meaning of participation in this model is that of *"being active participants in the practices of social communities and constructing identities in relation to these communities"* (p.4). In this sense, people belong to different communities of practice (at home, at work, related to their hobbies) and learning is not a separate activity from participating and being in these particular settings. However, learning can be intensified *"when situations shake our sense of familiarity, when we are challenged beyond our ability to respond, when we wish to engage in new practices and seek to join new communities"* (p.8), among others. On the other hand, we can not simply equate changing or learning with improvement and assume benevolence or efficiency of any community of practice. Wenger (1998) repeatedly urges caution in this direction: *"claiming that communities of practice are a crucial locus of learning is not to imply that the process is intrinsically benevolent. In this regard, it is worth repeating that communities of practice should not be romanticized; they can reproduce counter-productive patterns […] In fact, I would argue they are the very locus of such reproduction"* (p. 132). In this sense, the crucial point here is how to create an effective community of practice, in our case regarding appropriate teacher learning and school change, instead of one that reproduces bad habits and the sharing and construction of inadequate knowledge and beliefs.

Despite the framework of communities of practice is general, it has been widely used to inspire different classroom settings (classrooms as communities of practice) and, of course, for understanding teachers' learning. Within this framework, if we want people (let's say teachers) to create new practices (for instance develop curriculum, engage in inquiry, reflect and change their teaching…) we will have to make sure that our organizations (school settings or teacher groups) are contexts within which communities may prosper. We will have to value community building (giving importance to teachers' collegiality) and make sure that participants have access to the resources necessary (offering support and facilitation), to learn what they need to learn, in order to negotiate meanings, take actions and make decisions that fully engage their

own knowledgeability. According to this framework, by engaging actively, supportively and reflectively in these new practices, teachers learn. For instance, they learn the negotiated meanings within the community. Importantly, they also learn what they need to better engage in these practices.

4.2.2. 2. Professional learning Communities

Professional Learning Communities (PCL) are nowadays the most well-known and used community scenario for teachers and schools, in particular in the Anglo-Saxon context. According to Hargreaves (2007) *"PLC are, at this time, undoubtedly in the ascendant in educational policy and practice. Efforts to convert schools into PLC's (the abbreviation, like a nickname, itself being an indicator of increasing acceptance), are spreading rapidly throughout the English-speaking world".* (p. 181). The PCL framework is discussed in the literature as having its roots in early ideas of enquiry, reflection and self-evaluation of schools by Dewey; ideas of teachers as school and classroom researchers and curriculum developers by Stenhouse; and the idea of the teacher as a reflective practitioner by Schön, among others (see reviews of the field by Bolam et al. 2005 and Stoll et al. 2006). It is also highly influential, according to the authors, the school-based curriculum development movement of the 1970s in the US and UK, when interesting revolutionary notions for schools, such as the *thinking*, *problem-solving* or *creative* school were proposed. This early movement gave rise to ideas such as the *self-evaluating school* in the 80's (McMahon, Bolam, Abbott and Holly 1984) or the *knowledge creating school* in the 90's (Hargreaves 1999). The teachers that work in these settings need to be, as mentioned, *interactive professionals* (Fullan 1992) forming a *community of professionals* (McLaughlin and Talbert 2001). However, soon it was clear that this was not enough: to transform school and teaching practice, teachers need to learn, and keep on learning.

In this sense, regarding learning theory, professional learning communities are said to be based on certain ideas of the programme of Brown and Campione for students' learning "Fostering Communities of Learners" or FCL (Brown and Campione 1996; Brown 1997). In the words of Bruner, cited by Brown (1997), four crucial ideas underlied the FCL classrooms: agency, reflection, collaboration and culture*: "The first of these is the idea of agency: taking more control of your mental activity. The second is reflection: not simply "learning in the raw" but making what you learn make sense, understanding it. The third is collaboration: sharing the resources of the mix of human beings involved in teaching and learning. Mind is inside the head, but it is also with*

others. And the fourth is culture, the way of life and though that we construct, negotiate, institutionalize, and finally (after it's all settled) end up by calling "reality" to comfort ourselves" (p.87, emphasis in the original). These ideas for an effective classroom setting focused on learning are in the roots of any proposal of Professional Learning Community among teachers.

In the literature about PLC it is clearly stated that at the heart of the notion of professional learning community it is the notion of *community* in itself (Grossman, Wineburg et al. 2000; Couso 2002b). Westheimer (1998) highlighted five features of community that are the basis for any theory of community: shared beliefs and understandings; interaction and participation; interdependence; concern for individual and minority views and meaningful relationships. Based on this idea of community but including the important "learning of professional knowledge" focus, different definitions and proposals of PCL's have emerged. However, among this diversity of interpretations of the PLC concept (differences which sometimes are just due to contextual differences, for instance, different curriculum, schooling systems, teachers' background education and role in the workplace, educational policy agenda, etc.), the idea of professional learning community always suggests "*a group of people sharing and critically interrogating their practice in an ongoing, reflective, collaborative, inclusive, learning-oriented, growth-promoting way, and operating as a collective enterprise"* (Stoll and Louis 2007). In this sense, five key characteristics of the PLC scenarios are proposed: shared values and vision, collective responsibility, reflective professional inquiry, collaboration and a focus on group, as well as individual, learning (Bolam, McMahon et al. 2005).

The inclusion of the learning aspect in the title of professional learning communities deserves certain attention. By using explicitly learning (instead of just professional communities as in its origins), it is emphasised the central position that learning occupies in these scenarios. In PLC learning is both the tool for change and the goal of changing. PLC are communities (referring to the culture of collaboration) of professionals in the profession (referring to professional practice and professional knowledge), with the goal to foster learning, by learning in a job-embedded way. In this sense, the notion of PLC can be seen as a strategy to put into practice the idea of the *school as a learning culture*, which unfortunately is not generally the existing school culture. The traditional school culture has been described as a "black hole" regarding attempts of innovation and change (Stoll 1999), and unsuitable for fostering teachers' learning. For a *learning culture* we understand a culture where educational and working

activity (teaching, curriculum design, assessment,...) are considered and used as opportunities to learn and where learning is the ultimate goal of professional practice regarding students, but also regarding teachers and other educational agents. These ideas are at the source of the notion of PLCs: that of a community of learners, in the profession.

A community of learners (just another sort of community of practice in the aforementioned terms of Wenger and Lave) has particular goals, values and belief systems, but also discourse structures, for instance as a community of research, inquiry or reflective[30] practices. For doing so, the community relies on the development of a *discourse genre* in which constructive discussion, questioning, querying, and criticism are the mode rather than the exception. In this sense, a focus on discourse is quite interesting for analysing community and teachers' cooperative work in their workplace (Little 2002) (See also Publications 2 and 3 were Discourse Analysis and Content Analysis of teachers' discourse have been done to analyse teachers' cooperation). Through the new discourse, "*in time, these reflective activities become internalized as self-reflective practices"* (p.406, Brown 1997) and the learners in the community become discussants, questioners, inquirers and critical regarding their and others practice. What is pursued is a culture where a questioning, evidence-informed, reflective and self-evaluative attitude and action of all participating agents is promoted. Research and evaluation become central aspects of teachers' work, both referring to the acquiring of a more systematic approach to collect, analyse and use of evidence in the course of ongoing work and to the use of research results and evaluations done outside. In the same way as adults play as role models for children within communities of learners in the classroom, experts and teacher leaders can model discourse, reflective and inquiring practice for learning when working with teachers.

Today this sort of data-driven scenario is promoted by different circumstances. The broadening of the teachers' role within an accountability culture makes that more data than ever is available to teachers and researchers. Despite how this data is used if it is used at all is critical, it is the case that discussion of educational data has become more familiar than before, even achieving the media. It is also the case that ideas or instruments (for instance narratives, diaries, portfolios, professional journals,…),

[30] Within educational frameworks that stress the link between learning and inquiring, which are so common nowadays in the Science Education field, this idea of a *learning culture* is closely related to the idea of a *culture of inquiry.* In fact, in the literature one can find the terms Professional Learning Communities and Inquiry Communities used almost as synonyms.

originally from paradigms such as action research, practitioner research and reflective practice form part of many teacher education programmes and research projects. In this sense, the learning or/and inquiring culture were we situate our understanding of PCL implies data collection, analysis, reflection and change (McLaughlin and Talbert 2001). Other authors elaborate a little bit more on this idea under the term of reflective inquiry, which is fostered by: promoting research and evaluation across the school, in departments and by individual classroom teachers; adopting a more systematic approach to the collection, analysis and use of data and evidence in the course of ongoing work; and seeking out and using relevant and practical research, generated and produced by external researchers (Bolam, McMahon et al. 2005). In this sense PLC, in the notion of inquiry communities, give importance both to doing research and using research, or what is referred to having a both evidence-based and research-based approach.

Regarding their impact, Professional Learning Communities have shown to make a significant difference in terms of student achievement (Louis and Marks 1998; Bolam, McMahon et al. 2005; Stoll, Bolam et al. 2006). This is not only related with these scenarios as being good scenarios for teacher learning, but also related with being scenarios in which a common goal is pursued: improvement of students' learning. In this sense, some authors found that a collective responsibility for learning is significatively linked with an increase of students' results (Lee and Smith 1996). Other authors, however, discuss that the effects of professional community in changing classroom practice may be less than those suggested in the literature and provide a different view of these scenarios regarding their usefulness (Seashore, Anderson et al. 2003). For the mentioned authors, professional communities are not seen always useful to promote teachers' change (which is strongly dependant on individual teacher knowledge base, epistemology, beliefs etc.) but certainly to promote that certain change, if individually achieved, could persist over time and became school-wide. In this sense, these scenarios are related to the idea of *sustainability* of the development and change process. In the recent literature, authors are developing more the idea of sustainable Professional Learning Communities (Hargreaves 2007). This is important, as findings show that even schools that start out as innovative and are described as "breaking-the-mold" can lose their momentum and experience an "attrition of change" (Fink 2000). The importance of PLC in giving sustainability to change is, then, an important issue.

In achieving reality (being implemented in practice) PLC are also becoming controversial. In contexts were PLC are being implemented following the educational political agenda in a quite technical, and thus superficial way, divergences regarding their original moral rationale and approach to learning and professional development, and dilemmas regarding their usefulness and effectiveness in practice, are recently appearing and being discussed (Stoll and Louis 2007). One of the reasons behind this fact is that PLCs rely on something quite difficult to develop: trust. Activities common in learning communities such as mutual enquiry, team-teaching, classroom observation and feedback, mentoring partnerships and discussion about pedagogical issues and innovation, etc. are very difficult unless one feels confident and in a safe environment to do this, because there is a risk involved... Risk of being considered a bad professional (someone who needs to learn, who does not have enough knowledge and master of the profession, etc); risk to show too much of yourself when sharing your views and beliefs about pedagogy or subject matter; risk to lose autonomy when negotiating future action... This perception of risk is the seed, according to Perrenoud (1995), of the aforementioned teachers' isolation that he discusses as not just promoted by traditional school culture, but chosen by teachers as synonym of professionalism, capability and autonomy. It is thus not surprising that for some authors trust is the single strongest facilitator of professional community (Stoll and Louis 2007). But trust is very difficult to be constructed, in particular when there is a previous past of untruthfulness in the system. Trust is fragile; it takes time (which is usually underestimated, according to Thomas, Wineburg et al. 1998) and needs personal involvement. Here, the capacity of teacher leaders, researchers, etc. to motivate other participants is a key factor. Also to understand teachers and community rhythms: it is generally the case that the research or project agenda presses to go quicker than possible regarding the growth of trust in the community... For instance, the use of materials to promote peer feedback such as videos, despite its proven usefulness, can not be done at every stage of community formation neither in every case, because it is a very intrusive tool. Empirical research shows that teacher professional learning communities *"demonstrate a developmental trajectory in groups, specifically with regard to their capacity and disposition to dig deeply into matters of practice"* (p. 918, Little 2002).The research agenda has to suit the context and, more importantly, researchers within PLC have to compromise their roles both as facilitators of community and researchers, understanding that the former role is the one that should drive the agenda if something as complex as real change of culture, practices, beliefs and feelings wants to be achieved.

4.2.2. 2. Teacher learning in our publications

The mentioned ideas about teacher learning have implications regarding the publications that form this compendium. All three publications share the discussed socio-constructivist view of learning. Publication 1 uses this theoretical approach to guide the learning activities for teachers, sequenced and designed using the notion of the *learning cycle* (Karplus 1977; Jorba and Sanmartí 1996) and emphasising interaction and peer work among teachers. Publications 2 and 3 also refer to socio-constructivist theory to justify and discuss these collaborative settings as interesting for teacher learning and development. Because teachers, in these two scenarios, are situated in a different practice than the practice of teaching (doing curriculum design and discussing professional, social and political issues regarding science innovation in the school), we consider them to be interesting scenarios for teachers extended role's and practice discussed in the new view of professional development for bottom-up innovation. In Publication 3, in addition, some aspects of the rationale behind professional communities are used to interpret it, as the teacher group studied is an emergent professional learning community in which teachers start to share values and vision (they are in the process of doing so), show a *voluntary* collective responsibility (towards the materials they design), reflect on the process, collaborate and focus on group, as well as individual, learning (share meanings, materials, definitions, etc.) and have trust. In this sense, it is the scenario with more opportunity of sustainability, and has shown sustainable over the years.

4.2.3. Conceptions of teacher learning: relationships of knowledge and practice

One of the key questions regarding teachers' learning is what we think teachers should learn, because different answers to this question convey different images of the teaching profession and, accordingly, different professional development needs. Many authors have argued about the dimensions of teacher knowledge (Shulman 1986; Calderhead 1987; Shulman 1987; Tom and Valli 1990; Wallace and Louden 1992; Fenstermacher 1994; Goodson and Cole 1994; Calderhead 1996; Cochran-Smith 2000; Putnam and Borko 2000; Munby, Russell and Martin 2001; Darling-Hammond

2006). In general, authors agree that more than knowledge alone, we should speak about teachers' knowledge, believes and attitudes, because all them affect practice. In the words of Calderhead and Shorrock (1997) in addition to knowing "what" and knowing "how", teachers should also be competent in knowing "why" and knowing "when". Regarding what sort of "knowledge" is this, as we have described before, following Shulman (1987) teachers' professional knowledge has been widely conceptualized as content or subject-matter knowledge, pedagogical content knowledge (PCK) and general pedagogical knowledge. In the continental tradition and for the subject of science, these are referred to as scientific knowledge, both *of* science and *about* science following Hodson (1988); *didactics* of science; and general didactics or pedagogy.

Despite the interest in the nature of teachers' knowledge, when dealing with learning, the most important issue is how this knowledge is produced or generated. In this sense, one can find in the literature a classical separation between formal knowledge and practical or craft knowledge (Fenstermacher 1994). While the former is defined as the *knowledge base* for teaching, that is, the basic knowledge teachers acquire in pre-service and in-service teacher education; the latter is "*the integrated set of knowledge, conceptions, beliefs, and values teachers develop in the context of the teaching situation"* (p.141, van Driel, Beijaard et al. 2001)[31]. According to Cochran-Smith and Lytle (1999), this traditional distinction between formal and practical knowledge, in which the latter is perceived as having a lower status, is problematic. This is because *"it works to maintain the hegemony of university-generated knowledge for teaching and carries with it the same power and status differentials associated with the disconnections of basic from applied research and theory from practice"* (p.289). In this sense, for the authors this *dualism* among formal and practical knowledge is not useful for teacher learning and school change. Other conceptions of the knowledge to practice relationship, that is, what knowledge teachers need to learn, how and for what reasons, are necessary.

[31] Despite the importance the notion of Practical Knowledge has in education, which has even foster a line of research, for some authors referring to practical knowledge is wrong epistemologically, in the sense that there are not considerations of warrant or justification are attached to the concept. Instead, they suggest the use of this term as a type of reasoning (practical reasoning). (Fenstermacher 1994)

4.2.3. 1. Conceptions of teacher learning

According to Cochran-Smith and Lytle (1999), there are three main conceptions of teachers' learning or relationships of teachers' knowledge and practice. These are knowledge-*for*-practice, knowledge-*in*-practice and knowledge-*of*-practice. These three conceptions stand from a different standpoint regarding knowledge. While the first two are based in the mentioned distinction between formal and practical knowledge, the third one stands from a different relationship to knowledge. The interest in these different conceptions of teacher learning is, of course, that they imply different views of what is to be learnt, how and why. In this sense, it is interesting to discuss them when dealing with teacher learning.

The first conception, that of *knowledge-for-practice*, foregrounds formal knowledge as the base for improving practice. Formal knowledge is assumed to be university generated, consisting on general theories and research-based findings. This knowledge constitutes *the knowledge base* of teaching a particular subject. Teachers learn this knowledge in pre-service teacher education and traditional professional development activities. The emphasis of these initiatives is on helping new and experienced teachers come to know what is already known. Within this view, to improve teaching "*teachers need to implement, translate, or otherwise put into practice the knowledge they acquire from experts outside the classroom"* (p.255). The assumption behind this conception is that knowing more knowledge base (for instance more subject matter, more pedagogy or more instructional strategies) leads to more effective practice.

A second conception of the relationship of teachers' knowledge and practice is that of *knowledge-in-practice.* In this perspective the focus is on knowledge *in* action, that is, on the knowledge embedded in the practice or the reflection on practice of competent, experienced teachers (Schön 1983). This knowledge-in-practice, a *craft* and often *tacit* sort of knowledge, is implicit in the ongoing actions of expert teachers, in their good practice, and resonates with the notion of *practical knowledge* (Clandinin and Connelly 1987; Fenstermacher 1994; van Driel, Beijaard et al. 2001). This sort of knowledge is acquired mainly *"through experience and through considered and deliberative reflection about or inquiry into experience"* (p.262, Cochran-Smith and Lytle 1999). It is assumed, then, that teachers learn this knowledge when they have opportunities to examine practice and reflect on practice. This implies the generation of opportunities to articulate tacit knowledge, both at the individual but more importantly, at social level

(Zeichner 1994). For instance, *"facilitated teacher groups, dyads composed of more and less experienced teachers, teacher communities, and other kinds of collaborative arrangements that support teachers' working together to reflect in and on practice"* (p.263) are examples of contexts for teacher learning in this relationship. In these professional development initiatives, facilitators often work with teachers as supportive outsiders who push them to question their own assumptions and reconsider the bases of actions or beliefs. Besides more effective, as direct classroom practice is addressed, this perspective is also discussed to enhance the status of teachers' practical knowledge, acknowledging that professional expertise and knowledge comes in great part from the teaching profession itself.

In this framework of Cochran-Smith and Lytle (1999), the third conception of teacher learning is named *knowledge-of-practice.* In this conception, both knowledge generation and knowledge use are regarded as inherently problematic. The basis of this knowledge-practice conception is that teachers across their professional life span *"play a central and critical role in generating knowledge of practice by making their classrooms and schools sites for inquiry, connecting their work in schools to larger issues, and taking a critical perspective on the theory and research of others*" (p.273). In this conception, in contrast with the previous ones, it is not interesting to focus on differentiating the two kinds of knowledge because teachers *"stand in a different relationship to knowledge".* In this conception teachers, mainly through inquiry, make problematic their own and also others' knowledge and practice while co-constructing curriculum, developing local knowledge and taking critical perspectives. This is done within inquiry communities or other school-based collectives. Implicit in the *knowledge-of-practice* conception of teacher learning is the previously referred to image of professional practice that encompasses teachers' work both within but also beyond immediate classroom action.

The three different conceptions of learning, as they have been explained, convey different images of the teaching profession, and thus, of research into teaching. The previous two conceptions both refer primarily to what teachers do within the boundaries of their traditional roles as classroom managers. Research programmes here are focused on finding suitable didactical knowledge and on analysing teachers' practice. The third conception, however, emphasizes teachers' roles as co-constructors and creators of knowledge and curriculum, that is, sets a teacher researcher agenda.

These different views of the professional work also convey different professional development needs. Within the third conception professional development is seen as opportunities for teachers to both explore and question their own (and others') interpretations and practices. In this sense, *"teachers learn by challenging their own assumptions; identifying salient issues of practice; posing problems; studying their own students, classrooms, and schools: constructing and reconstructing curriculum; and taking on roles of leadership and activism in efforts to transform classrooms, schools, and societies"* (p.278, Cochran-Smith and Lytle 1999). According to the authors, these professional development scenarios are communities that involve joint participation of teachers and researchers who, despite bringing different knowledge and expertise to the collective enterprise, *"function as fellow learners and researchers rather than experts"* (p.278). The idea behind this knowledge-of-practice relationship is that of *inquiry as stance* described before, and the context is that of professional learning communities aforementioned.

This knowledge-of-practice relationship is related with ideas of teacher research, action research, or practitioner inquiry also described earlier (Elliott 1991; Gore and Zeichner 1991; Kemmis and McTaggart 1992; Kemmis 1997). This is because within this paradigm, either when developing curriculum, understanding children's work or investigating how students construct knowledge, teachers are involved in the systematic collection, analysis, and interpretation of some data. However, the goal of the communities that work within this approach is not doing research in the sense of producing findings, but to understand, articulate, and in ultimate term change practice, both at the classroom and institution level. In this sense, what counts as data or as evidence in these frameworks is more open even than in practitioner research, some people speaking about oral inquiry and teachers' talk as sources of interesting data. Despite the knowledge generated in these scenarios, as said, raises legitimate questions about its validity (Huberman 1996), Cochram-Smith and Lytle object that the approach of *inquiry as stance* generates knowledge of teaching that is primarily local, but can have also a public interest. The importance here lies not in whether the teacher is or not a *proper* researcher, but in the teacher not being a mere "*technician, consumer, receiver, transmitter or implementer of other people's knowledge*" (p.276). Other authors point out the importance of inquiry for obtaining new, contextualised knowledge for teachers in an era of *right answers* (Falk 2004).

Regarding this issue, Loucks-Horsley and colleagues (2003) emphasise the importance of a balanced situation, in which the content of professional development

(what teachers' have to learn) comes both from inside and outside the profession, that is, both from research (external research) and practice (reflection or inquiry on practice), because both have validity and importance regarding teacher professional development and change of teachers' practice. In the words[32] of Furió and Carnicer (2002), in agreement with other authors discussing the nature of Science Education (Porlán 1998; Gil, Carrascosa et al. 2000), teacher development *"has to be understood as a continuous process of theory-practice integration in which the teacher is conceived at the same time as learner and as innovator or researcher that participates in the construction of the "science of teaching Science", that is, of Science Education*" (p.47-48).

4.2.3. 2. Conceptions of teacher learning in our publications

In Publication 1 there is a *knowledge-for-practice* relationship between knowledge and practice, because the highly-sophisticated knowledge to be known (in this case, scientific knowledge and pedagogical content knowledge regarding the teaching of the energy degradation concept) can not be easily derived from or inquired in practice. This knowledge is formal knowledge which forms part of the knowledge base for teaching and it is obtained through standard science education research, within a particular research field. This is in coherence with the traditional training approach proposed in this scenario for learning such knowledge.

In Publication 2, teachers question about their practice and try to obtain knowledge by reflecting on their practice (in this case, their practice as participants in innovative school-based curriculum design). In this sense, this publication holds a *knowledge-in-practice approach*, considering that it is in the practice of these innovative teachers that interesting knowledge about the process of professional development in innovative contexts is embedded. This highly contextual knowledge, which depends on the teachers' experience, is not *"known"* before: being tacit, it needs opportunities such as the setting of Publication 2 to be made public and able to be discussed.

Finally, Publication 3 is an initial example of the *knowledge-of-practice* relationship. Within this scenario, teachers' develop their own curriculum within a design-based

[32] In the original: "*Este desarrollo ha de entenderse como un proceso continuo de integración teoría-práctica en la que el profesor se concibe como aprendiz en tanto que innovador o investigador que participa en la construcción de la «ciencia de enseñar ciencia», es decir, en la didáctica de la ciencia."* (p.47-48)

perspective, refining it according to results of actual implementation in practice. Despite teachers are not involved in systemic action research, in Publication 3 there is an *inquiry as stance* positioning, in which teachers hold a critical perspective regarding traditional curriculum and practice, and aim for their design activities to be evidence-based. In addition, teachers generate knowledge useful to other teachers, for instance embedded in the curriculum materials they design, which are done according to their own, collaboratively constructed, didactical rationale.

We agree with Cochran-Smith and Lytle (1999) that the last knowledge to practice relationship, that of *knowledge-of-practice,* is the most suitable one according to both our knowledge about how teachers' learn (in the socio-cultural, situative perspective) and our expectations of bottom-up reform. However, we also consider that teachers need to learn many different things across different settings. They need to learn an initial "knowledge base" in pre-service teacher education and update it along their professional life span. They also need to learn from their own and other teachers' practice, reflecting about it. All the knowledge a teacher needs to use in their complex practice is not possible to be produced by him or herself, neither by the teaching profession alone. For us, interesting of this idea of the different conceptions of learning is that it points out that with these two sorts of knowledge, formal and practical, it is not enough. Within this approach an important source of a teacher's professional knowledge should be lifelong collaborative problem-solving and inquiry in their workplace.

4.2.4. Teacher learning and teacher change

> "Change is governed by internal dynamics which are complex, autonomous, related to context, not submissive to external ideal models. If I were to use an analogy with Physics, the dynamics of teacher change would be more similar to the self-organising processes of the Physics of Chaos than to the deterministic ideal models of Classic Physics"
>
> V. Mellado (2003)
> *Cambio Didáctico del Profesorado de Ciencias Experimentales y Filosofía de la Cie*ncia

In the literature in the field of teacher learning and professional development *"it has been more or less assumed that teachers who know more teach better."* (p.249, Cochran-Smith and Lytle 1999). In this sense, many initiatives of professional development and teacher learning are designed as if there is a direct relationship between teacher learning and teacher change. However, as discussed in previous sections regarding the impact of traditional teacher in-service education, this is not always the case. In particular, there is not a direct relationship between all forms of teacher learning and substantial change in the practice of teachers.

There are different reasons behind this fact. First, not all opportunities for learning offered to teachers are actually addressed to the achievement of change[33]. Second, change has shown to be a very difficult and complex process, as the opening quote in this section points out. Third, researchers and teacher educators have proposed different models for teachers' change, some of them more difficult than others to achieve successful results. In the following, we will discuss these three interrelated issues.

[33] There are many definitions in the literature regarding the notion of "teacher change". Here, we refer to those changes in teachers' knowledge, beliefs and attitudes that affect, and thus change, teachers' practice. This practice is not restricted to teaching practice, to what teachers do within the classroom boundaries, but includes also other possible aspects of the practice of teachers within the profession: changes in their work as curriculum makers, as action researchers, etc. In this sense, we refer to teachers' change as teachers' both didactical (Tobin and Espinet 1989; Furió and Carnicer 2002; Mellado 2003) and professional change. We use the notion of teacher change to refer to the fact that the professional culture of Science Education must be transformed, and this requires extensive changes in teachers' deeply held beliefs, knowledge and habits of practice both regarding their work in the classroom and outside the classroom.

4.2.4. 1. Types of learning: transformative, additive and expansive learning

According to Thompson and Zeuli (Thompson and Zeuli 1999) all teachers' learning is not equal. The authors define *"transformative learning"* as the learning experiences particularly addressed to have a transformative effect in the teacher. In this sense, it is the learning able to produce *"changes in deeply held beliefs, knowledge, and habits of practice"* (p.342) of the teachers involved. On the other hand, there is another sort of learning scenarios, named scenarios of *"additive learning".* Through these learning experiences teachers learn new things or develop new skills, integrating them with what they already knew. In this sense, additive learning is the learning that adds to their current practice, rather than transforming it.

Historically, professional development has focused much more in additive learning than in transformative one. In general, traditional professional development *"has focused on only adding new skills and knowledge without helping teachers to rethink and discard or transform thinking and beliefs"* (p.46, Loucks-Horsley, Love et al. 2003) This is one of the reasons behind the discussed "lack of impact" on changing a teachers' practice of most in-service training. This is also behind the mentioned problem of fit between ambitious reform efforts and the professional development to support them. This traditional professional development, when well designed, can be successful in terms of adding knowledge to the teachers' existing knowledge base. However, it is not the right sort of learning scenario if teachers' change, both in the sense of changing deeply held knowledge, beliefs and attitudes and changing their own view of the profession, wants to be achieved. The expected learning outcomes of professional development addressed to additive learning have to be defined accordingly to the scope of these initiatives. We agree with Loucks-Horsley and colleagues (2003) that *"There is a place for both additive and transformative learning in teacher professional development, but there needs to be conscious choices of what is being added and what is being discarded, and why"* (p.46). Rather than discarded, we would have used transformed or evolved.

When referring to learning at the work place, Egenström (2001) uses the notion of *"expansive learning"* within a framework of cultural-historical Activity Theory[34].

[34] Activity theory is a psychological framework with its roots in the cultural-historical psychology of Vygotsky's. Its founders were Alexei N. Leont'ev (1903-1979), and Sergei Rubinshtein (1889-1960) who

Interesting in his proposal, in addition to the use of the activity system as a fruitful unit of analysis, is the idea of *contradictions* as the driving force of change in activity. Contradictions are not just problems or conflicts, but tensions within the activity system. For instance, tensions among the established rules, the goals and the division of labour. According to the author, the transformation of the activity, that is change, happens in expansive cycles. As contradictions emerge, there can be a deliberative collective change effort to expansive transformation. This expansive transformation is achieved *"when the object and motive of the activity are reconceptualized to embrace a radically wider horizon of possibilities than in the previous mode of the activity"* (p.137). In this sense, teacher change can only occur if there is a *reconceptualisation* (historical, social) of the teaching profession (the activity of teaching) and the objective of it (students' learning) to a wider horizon (not only teaching but also designing, inquiring, etc. and not only all students' learning but also teachers' learning). However, this *reconceptualisation* is what it is looked for when aiming at change. In this sense, in the view of the author, change it is not a matter of teacher (or institutional) learning of something already known to be able to change, but learning is what takes place as change is happening. *"People and organizations are all the time learning something that is not stable, not even defined or understood ahead of time. In important transformations of our personal lives and organizational practices, we must learn new forms of activity which are not yet there. <u>They are literally learned as they are being created</u>"* (p.137-138, emphasis added). Despite we find the definitions and work of the author very interesting regarding a substantial part of teachers' professional learning of "what is needed" to be a different, *extended-professionalised* teacher in different educational institution (a teacher who participates actively in school-based reform), we also consider that the previous notions of "additive" and "transformational" learning are useful regarding the also existing more structured knowledge based for teaching and the teaching profession.

---

sought to understand human activities as complex, socially situated phenomena, going beyond paradigms of behaviourism. Activity theory refers to individuals engagement and interaction with their environment, (activity) as something done by subjects to achieve certain goals. While doing so, tools are produced. These tools are exteriorized forms of mental processes, such as language, that become accessible and communicable to other people, thereafter becoming useful for social interaction. Activity also takes place in a particular context and culture, with particular rules and division of labour. This theory is usually represented by a triangle that has all these concepts as vertex and middle points, to show that all them influence each other in activity (subject, tools, goals, rules, culture and division of labour). This triangle is referred to as "activity system".

4.2.4. 2. Description of teachers' change

Even when transformative learning is pursued and teachers' change wants to be achieved, many professional development initiatives fail to produce it. In this sense, it is necessary to understand better what teachers' change is.

The conventional wisdom behind most professional development initiatives and reform rationales has been to focus their training efforts on changing teachers' beliefs, *"for when one believes differently new behaviours will follow"* (p.48, Loucks-Horsley, Love et al. 2003). However, research on teachers' change has shown that this is not a linear, but an iterative process. Instead of being linear, changes in ideas, attitudes, actions and behaviours occur in a mutually interactive process. "*On the one hand, people's current thoughts influence what choices they make and what they attend to as they plan and carry out educational activities. On the other hand, people's reflections on these activities and their outcomes influence their thoughts about educational matters"* (p.48, Loucks-Horsley, Love et al. 2003). In addition, the relationship between changes in beliefs and changes in practice does not always hold. Some research results show that often there are dissonances and contradictions between beliefs and practice for certain teachers and contexts (Lederman 1992; Mellado 1996; 1998).

Teachers' didactical and professional change is difficult and complex (Tobin and Espinet 1989; Mellado 2001; Davis 2003). On the one hand teachers' have personal practical knowledge (Clandinin and Connelly 1987; van Driel, Beijaard et al. 2001), constructed over the years mainly in the context of their classroom, which generally has shown successful enough. This knowledge is conservative (Tom and Valli 1990), rarely made explicit or reflected upon, can act as an obstacle regarding didactical change and is the starting point of the change process (Tobin and Espinet 1989; Gil 1991; Furió and Carnicer 2002), in the same sense as scientific alternative conceptions can make difficult the construction of more adequate scientific ideas and are students' starting point regarding future learning. In addition to their knowledge and beliefs, teachers have their own motivations, emotions and particularly important regarding change, self-esteem. This emotional part also plays an important role that should not be ignored (Hargreaves 1994a; Copello and Sanmartí 2001; Mellado 2003). On the other hand, teachers work in particular settings with particular cultures that greatly influence their practice. In this sense, some authors have point out to the need of resetting the "unit of change" towards the system rather than in the individual (Loucks-Horsley, Love et al. 2003). According to Davis (2003), to allow the social construction

of new knowledge and continued change *"power structures and discourse practices embedded within educational settings must be made explicit, examined, and transformed."* (p.27).

Due to these and other difficulties, in the literature change is described as an slow, ongoing and progressive process (Appleton and Asoko 1996). Different authors have suggested different phases for this process of change. Porlán and Rivero (1998) use an evolutionist framework to analyse teachers' change. According to the authors, the didactical change in teachers can be described as an evolution from traditional-transmissive didactical models to more innovative models, with different medium steps characterised by technological and spontaneous trends. Quite often the evolution from one of these models to another is not a matter of replacement but partial acquisition (Valcárcel and Sánchez 2000). Loucks-Horsley and colleagues (2003), on the contrary, use a model of teachers' change regarding what teachers focus on. For the authors, teachers' change over time evolve from self-oriented concerns to task-oriented concerns and only finally to a concern on the impact of the change. In this sense, the authors claim for "realistic expectations" if change wants to be achieved. Implementation needs *"several years in order for teachers to progress from an early focus on management to a later focus on measuring student learning"* (p.50, Loucks-Horsley, Love et al. 2003)

The importance teachers' give to students learning, which is the main reason why they engage in ongoing teacher development (Bell and Gilbert 1996), suggests that students' should have a privileged position in order to trigger teachers' change. For Guskey (2002) improvements in students' learning outcomes related to teachers' new practices is not one but *the* source of significant teachers' change. In this sense, he proposes a model for teacher change in which teachers' change their practices as a result of professional development but without changing their beliefs. It is not until the teacher gains evidence of the improvements these practices have produced in their students' learning results that the teacher actually changes. Ball and Cohen reported findings in this direction: in their project real changes in teachers' beliefs came after teachers have used the new practice and have seen the benefits it produced in their students, even though in the first place they implemented that practice without thinking it would succeed (Ball and Cohen 1999). For Guskey (2000) this means that "*it is not the professional development per se, but the experience of successful implementation that changes their attitudes and beliefs"* (p.139). The author proposes a model for teacher change that represents this idea (see Figure 5).

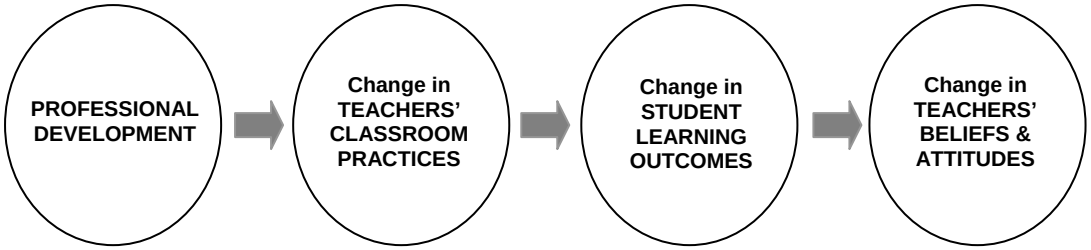


Figure 5: Model of teachers' change proposed by Guskey (2002)

Despite this model is quite rigid, in the sense that significant change can only be achieved in this particular way, it stresses the importance of teachers' trying out, testing in practice, reflecting on practice or inquiring their own practices for achieving change, which we agree are powerful strategies for teacher learning and change. However, we would not do such a strong hypothesis regarding how change happens. Within the framework of teachers' narratives[35], for instance, beautiful accounts of the change process by teachers' show how serendipitous, complex, chaotic and particularly multivariable this process is. An example: Fogarty (2001) recounts the four primary influences along her journey of personal change as the influence of a reading, the influence of a school culture, the influence of a mentor, and the influence of a student.

4.2.4. 3. Models of teacher change

The characteristics of teachers' didactical and professional change described in the above paragraphs come from research studies in the field in which scholars have analysed this process in detail. However, the cited and other authors from research on teachers' change are not the only ones that have ideas regarding teachers' change. All researchers and teacher educators in the field of teacher professional development have their own beliefs regarding teachers' change. These views of change guide their practice (as professional development designers, supporters or researchers) in the same way that teachers' views on students' learning guide their teaching practice, whether they research teacher learning or not. In this sense, it would be interesting to have models from which to "classify" existing views of teachers' change.

[35] Within this framework of teachers' personal stories, it is stressed that despite all personal professional journeys are unique, professional development lessons we can learn and we can use these lessons to soften the resisters. For instance, from Fogarty's or others' reflections, authors should re-dimension the importance of professional reading and narrative exchange among teachers.

In his review of teachers' educational change, Mellado (2003) uses analogical models from the philosophy of science to establish a parallelism between scientific change and teachers' didactical change. According to the author, one can understand better some aspects of teachers' didactical change when comparing it with how science "change" or, in other words, how scientific theories are evaluated and what conditions cause scientific progress. In this sense, Mellado describes three possible models of teacher change: a model of technical rationality, a model of conceptual change and a model of gradual change through internal development. Despite some of the themes discussed for each of these models have appeared in the previous sections, the interest here lies on linking these ideas within particular models analogous to those of the nature of science.

The model of technical rationality is analogous to the positivist-falsationist image of science. Within the positivist analogy, teacher change is seen as unproblematic: the teacher is a technician that applies *demonstrated* didactical theory transmitted by the experts, and learns practical knowledge through observation. Within the falsationist analogy, teachers' didactical change arises from teachers' dissatisfaction with their beliefs and practice.

The second model for teacher change is that of conceptual change (Posner, Strike, Hewson and Gertzog 1982), which the author compares with the scientific research programmes of Lakatos and with certain aspects of the Khunian paradigm change. Within this model, there is a "competence" between teachers' beliefs and the new, alternative didactical models presented to them. In this scenario teachers' change is also triggered by dissatisfaction with their theories. However, this is not enough. Teachers' central theories are resistant to change, and thus change won't happen without the teacher being offered real alternatives. In this sense, the new theories need to be understandable, plausible and useful for the teacher to accept them, either replacing previous ones or better, following new definitions of the conceptual change concept, changing their status. In this decision, personal and social aspects have also an important impact. Regarding the personal, the teacher need to feel empowered enough for undertaking change. Regarding the social, the school culture in which the teacher work is crucial for promoting or inhibiting change.

The third model of teacher didactical change is that of gradual change through internal development. In the words of Parke and Coble (1997) this model is that of

supporting ``*teachers to become architects for change through building upon their current conceptions instead of attempting to remediate them''* (p. 785). Following Mellado (2003) analogical exercise, this model can be seen as analogous to the epistemological notions of the research traditions of Laudan and the evolutionism of Toulmin. According to this model, teacher didactical change is seen as progressive instead of radical. Because it happens more by accumulation and ongoing transformation than by replacement, contradictions can easily coexist for a while. This progressive change occurs within a problem-based and inquiry approach, in which teachers engage in solving feasible (within the teachers' Zone of Proximal Development[36]) problems of their teaching practice. In this sense, change should affect all aspects of teachers' knowledge and belief systems, including conceptual, methodological and attitudinal ones. This model explains, for instance, the aforementioned lack of direct relationship found in the literature between teachers' epistemological beliefs and their practice, while also accepting that this does not mean that teachers are not already changing their views, or that their practice are not already changing. The *seed* of change could be there, coexisting with many other issues!

The third model of teacher change is also in agreement with previous notions of teacher development as self-development which can not be technically produced; neither it can achieve any ideal level (Terhart 1999). Teachers, as students, as people, as any learner can develop and change within their Zone of Proximal Development (ZPD) (Manning and Payne 1993). This fact also has consequences regarding the level of educational change or innovation that can be achieved in the system: as always, educational change is a matter mostly of teachers (also schools) change. Rogan (2007) speaks of defining an *appropriate* level of curriculum change in a given context and in a given time frame, so that there is no promotion of unrealistic innovation. He coins the term of zone of feasible innovation (ZFI), as parallel to the mentioned ZPD for learning, to refer to the extend to which curriculum development or innovation is feasible for certain teachers in their real contexts.

[36] The Zone of Proximal Development is a well-known term coined by Vygostky, defined as "*the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers"* (p.86, Vygotsky 1978).

4.2.4. 4. Teacher learning and teacher change in our publications

Regarding the sort of learning pursued, the three publications of this compendium are very different. Publication 1 is an example of an initiative addressed to *additive learning*, in the sense that teachers are not expected to change radically their classroom practice, but to add to their knowledge base some scientific and pedagogical content knowledge.

Publication 3, on the contrary, is an scenario where *transformative* learning needs to take place. The teachers of this learning community need to learn science and PCK (also about the concept of energy, for an interdisciplinary and context based teaching of it) and general pedagogy (for instance, strategies for students' cooperative work) to implement these materials in their practice. Despite it is not part of the content of the meetings analysed here, in subsequent meetings the teachers actually used their results from implementation to change their materials, reflecting on the reasons for those changes. Even though from the data we analyse (observations and teachers' cooperative discourse) we can not claim that the classroom practice of teachers actually changed during their group work, it can be said that their professional practice as curriculum designers actually did.

The distinction between additive and transformative learning is more difficult in Publication 2. The aim was for teachers to collaboratively reflect on their innovative practices so that they could elicit their practical knowledge (knowledge "learned" through the practice of participating in an school-based innovation). But we can not be sure if this learning was for the teachers additive or transformative. First, because the purposeful selection of teachers long involved in innovations make that for some of them these sort of reflections was not new while for others it really was. Second, because despite our intention was to have an input in transforming teachers' professional practice of participating in innovation towards a more reflective one, the time and organisational constraints of the context limited this possibility.

None of the three research studies of Publications 1, 2 or 3 is able to evaluate teachers' change. The aforementioned time and other contextual restrictions, such as changes in the membership of the group work or the following a funded project agenda, constrained the possibility of a long term, longitudinal analysis that could capture the ongoing and progressive process of change. However, the scenarios of Publications 1, 2 and 3 have been designed following some of the characteristics described before as

supporting teachers' didactical change. For instance, Publication 1 can be related with a model of conceptual change, while Publications 2 and 3 share more characteristics of the model of internal development. We do not go deeper in detailing these characteristics, as this has been done in the previous sections when referring to teacher learning.

4.2.4. 5. Who needs to change? A final (personal) comment

From all the above, it is clear that the literature in Science Education agrees that teachers' change is crucial: it is said that teachers need to change, to accept change, to learn how to change and to keep on changing over time. Even from ethical or theoretical views that refer to teachers' professional self-evolution instead of to radical change, a certain degree of change is always expected. We agree with this view. Teachers' change is important, as it is in any other profession. It is important because we are dissatisfied with students' results in science education, but it would be important too in a quite satisfactory scenario: it is difficult to imagine a situation of an excess of students' scientific competence that ceases our interest in science education improvement. In this sense, again, we agree that teachers' change is important. However, we also consider crucial to make explicit that, in this desirable changing and improving educational scenario, it is not only teachers the ones who have to change.

We have referred before to the fact that the new view of professional development also poses challenges to teacher educators and researchers: we also need to learn in order to be able to play our new roles efficiently. Now, we refer also to the necessity that science education researchers and teacher educators accept change, are able to change and keep on changing. First, we also have to keep abreast of the new knowledge in the field and extend our professionalism, becoming facilitators, guiders and supporters, in addition to researchers. Second, if we are going to be models for teachers and make speeches about the importance of change, we have to able to change ourselves. In this sense, I like to quote Charles and Shane (2006) when they ask the profession "do you, as staff developer, continue to pay attention to your own growth and learning; do you have a professional network or mentor with whom you challenge yourself? And, last, do you listen to your participants when they provide you signals and feedback that require modifications to your work or that challenge your beliefs?" (p.141). If we are not able to participate in change ourselves, we should not expect teachers' change, students change, or any change to happen.

Final Remarks to the Introduction

The theoretical framework presented in the previous sections have tried to justify, from different theoretical perspectives and empirical results, that a *new* view of professional development is necessary if *effective* educational change in science education is to be achieved. This *new* view of professional development is not that of professional development *for* reform: it goes beyond the traditional training activities provided to support reform. On the contrary, it accounts for professional development *within* reform, that is, for the professional development process that teachers can experience by participating in particular reforms and innovations: those which *place teachers and schools at their core*. From this *new* view of both professional development and innovation in education, an interesting feedback relationship is proposed between the two. Effective science education reform scenarios demand teachers play an active role and, in this sense, these scenarios challenge teachers' professional development. However, by playing this active role in the right conditions with the right support, teachers can develop professionally within these scenarios. When teachers and schools are placed *at the centre*, effective educational change scenarios can be effective professional development scenarios which, in turn, can be

effective educational change scenarios (see Figure 6). By analysing how different science education innovation scenarios promote professional development, and how certain characteristics of effective professional development are found in certain science education scenarios of innovation, the research project presented here explores the left and right arrows in Figure 6.

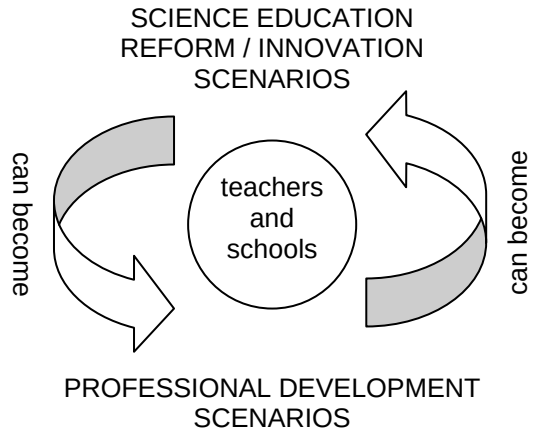


Figure 6: View of the relationship between innovation and professional development hold in this work.

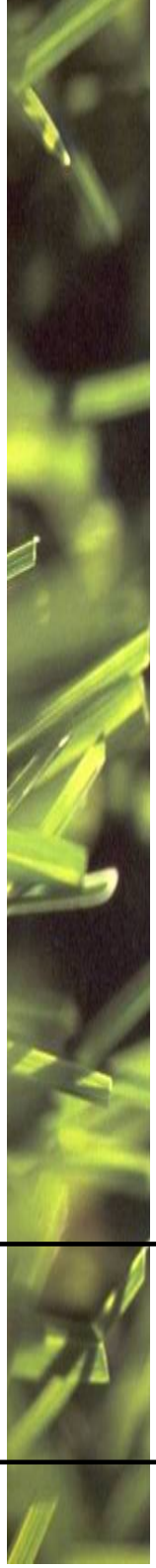
We have argued that the research works reported in Publications 1, 2 and 3 are examples of science innovation initiatives that, by placing teachers at their core in *different* ways, become interesting professional development scenarios in *different* ways, too. However, it is important to discuss how we know, within the research work presented in this thesis, the extent to which they actually are. At this time, not having done a direct empirical analysis, we have only answered this question theoretically. Within the previous theoretical framework, we have largely discussed what, according to the research literature, are the characteristics of effective professional development designs and scenarios; we have analysed what is known and believed about how teachers' learn in different settings and we have also considered proposed models of how teachers' change. While doing this, we have discussed which of the aforementioned characteristics are shared by the innovative scenarios of Publications 1, 2 and 3, and, in this sense, have justified theoretically their shortcomings and advantages as professional development scenarios for particular purposes.

In addition to this, we also have some particular research results from each of the research works reported in Publications 1, 2 and 3, which are presented and discussed in the next section of this work. However, these are not research results that directly answer the question or problem that drives this research: how different science education innovation scenarios promote professional development. This is because these pieces of research do not analyse empirically what professional development takes place in each of the science innovation scenarios they explore by using the same theoretical framework, focus, research questions and methodology for all of them, which would have been needed for them to become truly comparable. This ideal coherent research work has not been possible in practice for different reasons. On the one hand, it would have meant that we had a static or sufficiently static theoretical framework that could have been used in each of the subsequent researches done. Of course, it is never the case for any research that the theoretical framework is fixed at the beginning and does not evolve during the process. However, in our case this fact has deeper consequences. As the different researches reported in Publications 1, 2 and 3 were undertaken at different times, the new views on the topic of the researcher (and also of the literature) guide each new research design in an independent way. The contrary would have been an extremely artificial research scenario. Due to the fact that in our case these views on professional development have evolved substantially, as shown by the broad territory that it is covered from science innovation supported by notions of training to science innovation within professional learning communities, to think of a single research design for all of them is especially difficult. For the broadly different conceptions of science education innovation (and also of research) embedded in the views of teacher, learning and change of Publications 1, 2 and 3, issues of focus, instrument, unit of analysis, methodology and others arise, making the use of a single method to analyse the professional development potential of each of them very complicated.

On the other hand, this research work joins together different *real* research pieces undertaken, as said, within an evolving framework, but also in different contexts, at different times and belonging to different research agendas. In this sense, the research projects of Publications 1, 2 and 3 have neither been carried out, nor reported, with the primary purpose to illuminate the broad problematic this dissertation deals with, a problematic that did not exist in the mind of the researcher when they were designed. These pieces of research, on the contrary, were designed to answer concrete research questions that have meaning in the contexts in which they were undertaken, within the projects' rationales to which they belonged; and have been published following

reporting constraints and addressing particular audiences. Because each of the research followed particular research interests, questions and goals, we can not offer *direct* empirical answers from their results to the research problem addressed here. They do not include a sample and do not follow a methodological design purposefully chosen to explore science education reform scenarios as Professional Development scenarios.

However, this does not mean that from Publications 1, 2 and 3 we have no empirical evidence of what professional development is taking place. Each of these research works analyses different aspects (reflection, collaboration, etc) and indicators (conceptual change, empowerment, identity, leadership, meta-cognition, etc) of professional development, and do so in different ways. From these different analyses, interesting issues regarding characteristics of the professional development that takes place in each of these innovation scenarios emerge. Also, they offer results regarding the characteristics of the innovation scenarios that seem to have a deeper impact on the professional development of teachers. By doing so, the research works of Publications 1, 2 and 3 offer research results for the exploration of how different science innovation scenarios promote particular aspects of professional development. In this sense, and despite the methodological limitations that presenting this research work as a compendium of publications shows, the particular research problem posed within this theoretical framework is addressed in the three publications included in the next section. A global discussion of results and conclusions is also included in the following.



SECTION 2. Publications

Publications

The thesis presented here is a compendium of the following published papers:

4. Pintó, R., Couso, D., Gutiérrez, R. (2005) Using Research on Teachers' Transformations of Innovations to Inform Teacher Education. The Case of Energy Degradation. *Science Education*, 89 (1), pp. 38-55.

5. Couso, D., Pintó, R. (2007) Teachers' Collaborative Reflections about School-Based Science Innovation in Spain. In Lang, M., Couso, D., Elster, D., Mooney-Simmie, G., Klinger, U. & Szybek, P. (Eds) *Professional Development and School Improvement*. Cap. 3, pp. 75-118. Studienverlag: Viena (Àustria)

6. Couso, D., Pintó, R. (*in press*) Análisis del Contenido del Discurso Cooperativo de los Profesores de Ciencias en Contextos de Innovación Didàctica. *Enseñanza de la Ciencias,* ICE-UAB: Barcelona.

5. Publication 1

Using Research on Teachers' Transformations of Innovations to Inform Teacher Education. The Case of Energy Degradation

Publication 1 of this compendium reports part of the research done by the author, supervisor and other colleagues within the research **project STTIS** (*Science Teachers Training in an Information Society*), funded by the European Commission, DG Research, within the TSER programme. (Ref: ERB-SOE2-CT97-2020), from 1997-2000.

The STTIS project studied the transformations teachers made of different types of innovations in Science Education when implementing them in practice. According to the project rationale, the most critical phase in curricular innovation is its implementation in school praxis, in which teachers play a decisive role as innovation transformers. In this sense, STTIS research this process of transformation in order to obtain knowledge that can favour the relevant implementation of innovation. A central issue in the STTIS project, then, is to analyse teachers' role and possible blockages when confronted by innovations, and to investigate the factors that influence the quality of take up. The objective is to achieve a better mutual adaptation between teachers and innovation. This is done both by better adapting the description and presentation of innovation to teachers and by designing new materials and specific strategies for teacher training.

This Spanish contribution to STTIS research on transformations of curriculum innovations studies the implementation of a particular innovative teaching sequence on energy degradation in Spanish secondary schools. In Publication 1, the conceptual clarification of the concept of energy degradation intended to in this sequence is described. The paper reports the specific transformations found in teachers' interpretations of the rationale for the teaching sequence, analysed using video-data of teachers' implementation in practice of the studied innovative curriculum and data from teachers' interviews. Some of these transformations were considered substantially

problematic, in the sense that according to the extensive literature in the field of Science Education regarding the teaching and learning of Energy, they could give rise to alternative conceptions about energy degradation and related concepts in students. These teachers' conceptions about energy degradation were found not only in the case of Spanish teachers, but also by other researchers within the STTIS project and also previous research. As such, these alternative conceptions of energy degradation show to be widespread and persistent. As a consequence, the paper proposes a research-based teacher education proposal, based on a workshop and some teacher education materials, specifically aimed at overcoming the difficulties encountered. The teacher education proposal designed is underpinned on constructivist theory, and relies on the idea of a learning cycle to facilitate changes in teachers' conceptual understandings, through both co-operative work and reflection on practice. In the paper, despite it is discussed that the teacher education proposal is just one way of addressing the problem of profound teachers' alternative conceptions and that other teacher education scenarios could be perhaps more helpful, it is also discussed that these are not generally available. The use of a research-based approach and a socio-constructivist theoretical framework for the design of this teacher education scenario is discussed to promote teachers' learning within the constraints of the short-term, narrow-focus teacher education programmes available.

Using Research on Teachers' Transformations of Innovations to Inform Teacher Education. The Case of Energy Degradation

ROSER PINTÓ, DIGNA COUSO, RUFINA GUTIERREZ
Departament de Didàctica de les Ciències, Universitat Autònoma de Barcelona, Facultat d'Educació, Edifici G5, Campus de la UAB, 08193 Bellaterra, Spain

Received 10 June 2002; revised 19 December 2003; accepted 23 April 2004

DOI 10.1002/sce.20042
Published online 24 November 2004 in Wiley InterScience (www.interscience.wiley.com).

ABSTRACT: This Spanish contribution to the STTIS (Science Teacher Training in an Information Society) investigations of transformations of curriculum innovations studies the implementation of a particular innovative teaching sequence on energy degradation in Spanish secondary schools. The paper describes the transformations found in teachers' interpretations of the rationale for the teaching sequence that could give rise to alternative conceptions about energy degradation and related concepts in students. Research-based teacher education materials aimed at overcoming some of the difficulties encountered have been developed. The materials rely on the idea of a learning cycle to facilitate changes in teachers' conceptual understandings, through co-operative work and through reflection on practice. *Sci Ed* **89:**38–55, 2005

INTRODUCTION

There has been extensive research into the teaching of energy, over the last two decades (Arnold & Millar, 1996; Bécu-Robinault & Tiberghien, 1998; Driver & Millar, 1985; Domenech, 2000; Duit & Haussler, 1983; Kesidou & Duit, 1993; Martinez & Perez, 1997; Pintó, 1993; Solomon, 1985; Trumper, 1993; Van Huis & Van Der Berg, 1993; Viglietta, 1990). The earlier research studies focused on the identification of students' difficulties; later ones made proposals for new approaches. Behind many of these proposals lie a wide range of very interesting theoretical contributions and reflections on energy and its teaching (Arons, 1999; Duit, 1981, 1983, 1987; Hicks, 1983; Ogborn, 1983, 1986, 1990; Saltiel, 1997; Tiberghien, 1996; Vicentini & Mayer, 1996). However, despite the fact that a great deal of effort has been put into working out innovative strategies aimed at improving students' understanding of energy, there is still much dissatisfaction with the effective impact of such strategies in schools.

Correspondence to: Roser Pintó; e-mail: roser.pinto@uab.es

Light could be thrown on the causes of this lack of impact by a better understanding of the process at work between the design of an innovation and putting it into practice. This could help curriculum developers and designers to propose and present innovations more successfully. Teachers play a central role in the process, as it is they who turn the innovation into a classroom reality. A teacher dealing with an innovation explicitly or tacitly accepts, rejects, or modifies various aspects as seems appropriate; that is, teachers transform an innovation through their interaction with it. In Black and Atkins's words (1996): "Teachers do enter into dialogue with innovation. The new practices and the old interact in complex ways. We can picture the new and the old overlapping to create a zone of turbulence and challenge" (p. 148).

The existence of such a *zone of turbulence and challenge* where the old and the new meet cannot be avoided: for instance, teachers have no choice but to adapt the innovation to their own teaching style and their own classroom/school context. But the interaction leads also to other transformations that are related to teachers' knowledge of and beliefs about the subject matter, and their beliefs about themselves and about teaching and learning (Pintó, 2005, this issue). These transformations[1] can enrich an innovation, because the interaction of innovation, teacher and pupils provides it with "new life." However, in many other cases curriculum developers and teacher educators claim that the transformations teachers make in practice do not conform to their original intentions (Geddis, 1991; Huibregtse, Korthagen, & Wabbels, 1994; Johnston, 1991).

With the aim of providing greater knowledge of this transformational process, the STTIS[2] (Science Teacher Training in an Information Society) project analyzed the "putting into practice" of different types of teaching innovation across five European countries (Pintó, 2005, this issue).

In this paper, we present the part of the STTIS results concerning the implementation by Spanish teachers of an innovative teaching sequence on energy degradation. Teachers' transformations of an innovative teaching proposal were observed and analyzed. The results were used to design and develop a workshop for teacher education.

THE INTEREST OF TEACHING ENERGY DEGRADATION

Many writers (for example, Cardenas & Ragout, 1996; Sciarretta, Stilli, & Vicentini, 1990; Solbes & Tarin, 1998; Solomon, 1982, 1987) have pointed out the value of teaching the idea of energy degradation, as a very intuitive concept that makes it easy to describe real phenomena. Instead, in physics courses for secondary schools there is a tradition of stressing energy conservation. In everyday language, it is often said that energy is being "used up," that there is "waste" of energy and that it is necessary to save energy, etc. "Conservation" of energy then appears to mean being careful not to waste energy, as opposed to the scientific statement that the total energy of the universe remains constant (Goldring & Osborne, 1994).

These everyday understandings of energy "conservation" have led to the conclusion that what is in everyday speech is called energy, corresponds in thermodynamics with the non-conserved quantity free energy (Ogborn, 1990). For some authors (Duit, 1981; Kesidou & Duit, 1993), this apparent contradiction between the everyday experience of energy waste and the scientific idea of energy conservation can be overcome by introducing students to

[1] In this paper, we say that a transformation has been produced when a difference is observed between what has been proposed and what has been observed. In this sense, transformation is a neutral concept that indicates a change.

[2] STTIS (Science Teacher Training in an Information Society) is a research project funded by EU, DGXII, within the framework of the TSER programme, N° SOE2-CT97 20 20, coordinated by R. Pintó, UAB. http://www.blues.uab.es/~idmc42

the concept of energy degradation, that is, the idea that in real processes energy is conserved but progressively becomes less useful.

Energy degradation states that energy loses quality, not quantity, during real processes, so that what can be talked about as decreasing is the energy availability of the system. As the authors mentioned above point out, energy degradation is like a *missing piece* necessary for a complete construction of the energy concept. Our view is that both the concepts of energy degradation and energy conservation need to be related to and distinguished from one another for a proper understanding of the concept of energy.

Energy degradation is also a useful concept to be used in introducing the idea of the directionality and irreversibility of natural processes. Many authors have argued about the appropriateness of introducing the second law of thermodynamics to preuniversity students. Solomon, as far back as 1982, showed how the idea of "running down towards sameness" is already present in very young students, and Ross (1988) stated that the second law of thermodynamics "is part of common experience." Following them, Goldring and Osborne (1994) state that ". . . the second law of thermodynamics, in some suitable form, should form part of the energy syllabus, even for young pupils . . . " (p. 26).

Some ideas related to the second law, such as the idea of a lack of symmetry in natural processes (Atkins, 1994), as well as the tendency towards uniformity, "the tendency to decrease differences" (Ogborn, 1990), can easily be introduced at a qualitative level through the energy degradation concept[3] (Boohan & Ogborn, 1996). As Ogborn (1986) pointed out, ". . . talk of degraded forms can be no more than shorthand for saying that the total entropy has increased" (p. 31).

METHOD AND SAMPLE

The previous section explains our interest in the introduction of the concept of energy degradation into the teaching of energy. In Spanish secondary schools, this introduction is certainly an innovation: Spanish teachers do not usually teach about energy degradation in their teaching of energy. Using the ideas discussed above, we developed an instructional sequence about energy to introduce energy degradation to 15–16-year-old students (Pintó & Gómez, 1999). One of the most important aims of the sequence was to facilitate students' switch from everyday to scientific language on this topic. This focus on the use of language is related to the important role it has in science. As is well known, in science a strong effort is made to define scientific terms precisely, each conveying a specific single meaning.

Two different types of resources were included in the instructional sequence:

(a) A program containing objectives, contents, and teaching orientations for the practical implementation of the instructional sequence by teachers. The program justified in some detail the selection and sequencing of content. The teaching orientations were to act as a guide for teachers.
(b) A booklet "L'energia" containing theoretical content and practical activities for students. These recommendations for student activities also aimed to help the teachers who used them.

[3] The concept of entropy, as such, was not introduced in the proposal because it was excessively distant from the content usually taught. Spanish teachers often consider it too abstract, more related to chemistry than to physics, and difficult for students to understand (Pintó, 1991). Knowledge of the different formulations of the second law of thermodynamics has been shown to be unusual both amongst teachers (Pintó & Gómez, 1999) as well as amongst physics undergraduate students taking thermodynamics courses (Pintó, 1991).

In this paper, we discuss only those aspects of the sequence directly related to the concept of energy degradation. The following, in qualitative terms, summarize the specific innovations included

- introduction of the idea of energy degradation during a process as the loss of energy availability or capacity to do useful work;
- introduction of the idea of energy dispersion[4] during a process as its distribution among many particles or among parts of a system;
- interpretation of real (everyday) processes where a component of a system or a subsystem is being heated (due to friction, motion, etc.), as long as the energy is being degraded; use of the concept of internal energy to interpret such heating.

In a formal session (about two hours), the STTIS research project was presented to a group of 20 teachers, all with a scientific background (most of them, 11 of 13, were physics or chemistry graduates). They had been selected because of their considerable experience in secondary school teaching (from 4 to 20 years). The rationale of the teaching sequence on energy was presented. The differences between the innovative sequence and traditional teaching were discussed (especially those related with the new "language" of the innovation) and the reasons for these differences were explained. During this session, the particular aims of the research and the workplan were also described. Teachers who expressed their interest in teaching the new sequence on energy and who were willing and able to collaborate with the researchers (giving opinions about the proposal, talking about their teaching sessions, and analyzing them) were selected.

In a second meeting session, the materials for the course (the program with teaching orientations for implementing the sequence and the students' booklet "L'Energia") were given to the teachers, along with a brief presentation of their contents. A large schema showing the selection and sequencing of the contents in "L'Energia" was discussed for about one hour. Because in this research we were interested in transformations of innovations in a "normal" context, we tried to reproduce the way the official syllabi are usually presented to teachers; for this reason no other specific prior training was provided.

The teachers' implementation of the innovation was followed and supported when required. Data were collected from different sources, allowing cross-checking to increase the reliability of results. Table 1 shows the sample and what, when and how data were collected. Figure 1 describes the processes of data gathering and cross-checking followed throughout the research.

RESULTS

On the part of the teachers selected, satisfaction with the implementation of the innovation was communicated in various ways. When suggestions were requested during the first interviews, the teachers did not propose significant changes either to the sequence or the booklet. In many cases, they made explicit their agreement with the scientific approach of the innovation. The booklet "L'Energia" was widely used, and in good measure the students did the exercises and activities that it contained.

[4] In the didactical transposition (Chevallard, 1985) we have chosen in this research for secondary school teaching, the concept of energy dispersion is understood as a microscopic explanation of energy degradation. Energy degradation is then explained as energy becoming more spread out and rearranged amongst particles. For instance, in the case of an object in motion and taking into account the friction, it allows us to relate increases of temperature in the rubbed surface to its increase of internal energy.

TABLE 1
Details of the Process of Data Gathering for the Identification of Teachers' Transformations of Innovative Proposals

Data to Collect	Time to Collection	Precedure for Data Collection	Sample
Interpretation of sequencing of contents	After reading the program before implementing the proposal	Semidirected interviews	13 teachers
Process of the implementation	During the teaching of the selected concepts (degradation, conservation, and dispersion)	Classroom observations notes and video recording	9 teachers, about 3 h each
Opinions on the proposal	After the proposal was implemented	Not structured interviews	5 teachers

Teachers' transformations of the innovation were identified from the observations made during the implementation of the teaching sequence, and from the pre- and post-interviews about it. Some of these transformations involved adapting the innovation to the teachers' own style and context; in some of these cases this improved the innovation. However, some other transformations were inconsistent with the rationale for the innovation (to which these teachers had previously agreed) or revealed inappropriate conceptual meanings. Because this innovation introduced new scientific concepts for teaching a well-known topic, these inconsistencies or distortions of the rationale imply different understandings or conceptions than those previously agreed upon. In this paper, we focus on these distorting transformations of the rationale, in particular those showing teachers' conceptions of the energy degradation concept that are inconsistent with the scientific view taken in the innovation.

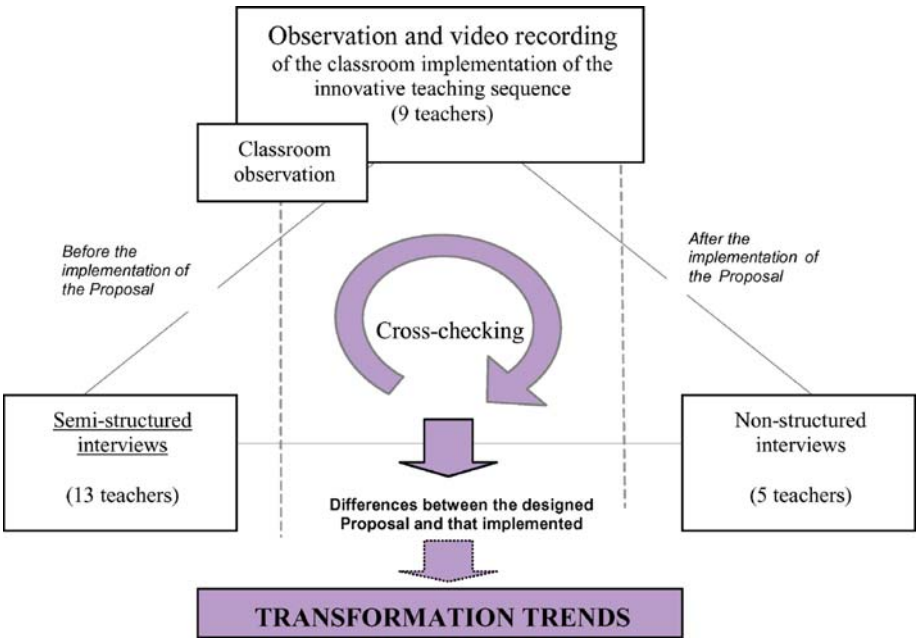


Figure 1. Description of the processes of data gathering and crosschecking followed throughout the research.

To identify teachers' conceptions that are inconsistent with the rationale, we analyzed their discourse in classroom and interviews, that is, the language they used to implement and to reflect on the innovation. In the instructional sequence, special care was taken over the language used to express scientific ideas: the innovation could be understood as a new "language" for teachers to learn. Other authors have written of the different languages that may be associated with different scientific "didactical transpositions" (Chevallard, 1985), for instance Kaper and Goedart (2002) argue the value of "the forms of energy language" as an intermediary language for students to carry them from everyday language towards thermodynamic language. In our case, the language of our innovation about energy degradation is close to what is currently agreed in thermodynamics. Whilst it is true that the same idea can be expressed in many ways, we could detect concepts being consistently formulated in such a way as to convey a meaning divergent from the scientific view. We also detected misinterpretations of the intentions of the choice of language used in the instructional sequence. From the perspective of the STTIS project, these were interpreted as distorting transformations of the instructional sequence, revealing alternative conceptions of energy degradation. Language is of course not the same as thought. But we do take the choice of language here to indicate teachers' thinking either about scientific concepts or about what science to teach. In both cases language use in the classroom, being a tool of mediation between teacher and students, requires special attention. The literature on teachers' teaching and its relationships with students' learning provides arguments for this attention. In particular, when alternative conceptions are embedded in teachers' classroom explanations, they interfere with students' scientific comprehension and make it difficult for them to understand new insights (Gallagher, 1991; Lederman, 1992; Linder, 1992; Moje, 1995; Sanchez & Valcarcel, 2000; Smit & Finegold, 1995; Strömdahl, Tüllberg, & Lybeck, 1994).

Teachers' Conceptions of Energy Degradation

The following list shows some of the observed alternative conceptions of degradation, which have been organized into categories to summarize the main features related to each. This categorization has been validated by crosschecking with the results obtained from other parts of the STTIS research, in particular from the semiotic analysis of teachers' transformation of the images used in the innovation to represent scientific concepts (Ametller & Pintó, 2001). These conceptions are not associated with individual profiles: a single teacher can hold more than one of these conceptions, or none at all.

Energy Degradation as Opposed to Energy Conservation. Most teachers related energy degradation to energy conservation; however, on certain occasions, such connections were seriously incoherent. We found teachers who proposed models to their students such as the following:

> If the environment is part of the system, then energy is conserved. However, if the environment does not take part in the system, then energy is degraded and dispersed

In other words, it looks as if they explained to their students that energy only degrades when it is not conserved: degradation as in opposition to conservation. An appropriate link between the two concepts is missing.

Energy Degradation as Energy Transferred to a Different Place. In the classes observed, we detected a conception about energy degradation describing it as a change in location. That is, energy degradation is seen from the energy transfer perspective:

> . . . energy has been degraded, that is, it has gone into the surrounding environment, it has been transferred to the air and this is why you cannot use it.

Energy degradation seems to be interpreted as energy going from one place to another. This is stated even more clearly in

> You should no longer say: energy has been lost; instead you should say: it has been transferred.

The change of quality of energy is not stated as a decrease in the capacity to do work but is explained in terms of a change of location.

Energy Degradation as a Decrease in the Amount of Energy. In some cases, energy degradation was referred to as a decrease in the quantity of energy instead of a decrease in its quality (or availability to do useful work). One teacher said

> If we have an initial system and a final system, those systems will have a certain amount of energy . . . if at the end, one of the systems has less amount of energy, this means that energy degradation has taken place.

The wording "less energy" or "energy lost" could not be interpreted as losing available energy or "useful energy" but only as a decrease in its quantity.

Energy Degradation Not Related to Internal Energy. The teachers used many concepts to give an account of energy degradation, but that of *internal energy* was scarcely mentioned. We noted how a loss in the quality of energy when there is friction, together with an increase in temperature, is explained through sensory perception: "the pieces heat up." However, explanations about the parts of the system warmed during the process of friction as undergoing a temperature increase because of an increase in their internal energy were never found, and the relation between this process and degradation was not stated explicitly (despite this being part of the teaching sequence).

Degradation as Heat. The teachers talked about heat and heating to refer to the decrease of the "quantity and quality of energy." It was pointed out on many occasions that

> Those are leakages of heat from the system

Or, more usually,

> Energy has been lost as heat.

Heat is no longer seen as a way of transferring energy among systems but as a process of losing energy or losing the availability of energy.

Energy Degradation as a Change of Energy Form. We also detected the concept of degraded energy being seen as another kind of energy; as a different energy form

> Energy degradation means changing into another type of energy.

The change in the quality of energy seems to be understood as a change in its nature: as a kind of ontological change.

These conceptions are also present in the teachers' treatment of the images from the same sequence (Ametller & Pintó, 2001).

There may be many reasons for teachers to make these kinds of statements. But it is important to remember that teachers' explanations are being given to students who cannot distinguish what is familiar language from what is scientific. This is why we consider that teachers' accuracy in the use of words should be very seriously taken into account. Remembering that the teachers in our sample had all willingly agreed to collaborate in the innovation, we might interpret such transformations as arising because they had not completely internalized the rationale for the innovation (Sassi et al., 2001). Such a lack of awareness of the important innovative features in the sequence (especially related to its language) could be related to insufficient or inappropriate stress on these features in the material given to them. It could also be attributed to teachers' difficulties in dealing with new scientific or theoretical knowledge.

In the literature, similar misunderstandings are usually related to teachers' knowledge systems and their epistemological beliefs about subject matter content (Pintó, 2005, this issue).

The transformations described here, together with transformations detected in parallel by other STTIS research groups, fit with general trends of transformation seen when different types of curricular innovations are implemented (Pintó et al., 2001). Especially significant for innovations in teaching energy degradation were the tendency to fragment holistic views or approaches and the tendency to modify small but crucial details and to reduce the refinement of language.

DEVELOPMENT OF A WORKSHOP CONFRONTING OBSERVED TRANSFORMATIONS

The training workshop described here aims to help teachers to confront conceptions that they may have that are inconsistent with an adequate view of energy degradation. It is intended to help teachers to adapt the innovative sequence in a manner consistent with its scientific rationale, and to promote their awareness of the essential points of the innovation: its advantages over more traditional sequences, the new "language" associated with it, etc. And it is designed to reduce the chance that teachers' alternative conceptions will be taken up by their students.

Schoon and Boone (1998) give added importance to the need for such training materials, pointing out how certain alternative conceptions are particularly critical:

> . . . not all alternative conceptions are of equal importance to the science educator. Some alternative conceptions may be important only to a small segment of today's science teachers; holding these "wrong" ideas simply does not greatly interfere with a person's ability to cope in today's world or even to learn more science. However, other alternative conceptions may indeed be barriers to learning more science, learning about science, and perhaps appreciating science, as well as feeling good about one's own abilities to teach science. (p. 565)

They see alternative conceptions about energy degradation as fundamental barriers to science:

> understanding that [. . .] electricity is not used up in light bulbs or other appliances is basic for [. . .] the study of energy in physics. (p. 565)

Theoretical Basis of the Design of a Teacher Training Program

The design of the teacher education program presented in this paper relies on both the empirical data related to energy degradation and certain theoretical foundations for effective teacher-training strategies. We especially lean on three main theoretical features: a socio-constructivist view of learning, a metacognitive perspective of conceptual change, and the use of a learning cycle for sequencing the activities. The first two are discussed in the introductory paper (Pintó, 2005, this issue), as part of the STTIS general framework, so we give here only a brief account of the main aspects that we want to emphasize.

A Socio-Constructivistic Perspective of Learning. From this perspective, the focus of teaching has to be on the development of "intersubjective interchange" (Anderson, Howe, & Tolmie, 1996; Beeth & Hewson, 1999; Duschl, 1994; L'Oughlin, 1992).

In this sense, interaction among teachers and between teachers and teacher trainers should be the key tool for meaningful learning.Thus this model stresses the value of discussion and collaboration as methods for promoting teachers' learning.

A Metacognitive Perspective of Conceptual Change. Strategies for conceptual change in science education have been widely researched (Hewson, 1993; Hewson et al., 1992; Summers & Kruger, 1994; Thorley & Stofflett, 1996; Zuzovsky, 1994). De Jong, Korthagen, and Wubbels (1998) claim that the application of this methodology for teacher education has been shown to be very efficient. Thus we envisage that the central activity and main focus of teacher education about innovation should encourage conceptual change through reflection on cognitive conflict (Hewson et al., 1999). With Wiser and Amin (2001), we understand conceptual change as having both revolutionary and evolutionary components. The everyday conceptualization continues to be held alongside the scientific one and the context will trigger one formulation or another. That is, conceptual change is not understood as a simple replacement of one conception by another. What changes is the status of different, sometimes competing, conceptions (Hewson & Hennessey, 1992) and this status is context dependent. Thus we do not expect in the teacher training materials presented here to be able to replace teachers' everyday language by the language of the innovation, but rather to make teachers aware of the educational risks of using the everyday language in the school context.

In this sense, we see teachers' conceptual change from a metacognitive/reflective perspective in agreement with the contextual view of Fensham, Gunstone, and White (1994):

> [. . .] an accretion of information that the learner uses to sort out contexts in which it is profitable to use one form of explanation or another. (p. 6)

Sequencing Teaching Activities in a Learning Cycle. We designed the teaching activities of the teacher education program to follow a learning cycle. The learning cycle is based on the original idea of Karplus, Lawson, and Renner "exploration, invention and

discovery" (Karplus, 1977; Karplus & Lawson, 1974; Lawson & Wollman, 1976; Renner & Lawson, 1973), but has been expanded and adapted to the other perspectives discussed above. The phases of the cycle are called exploration, introduction of new contents, restructuring, and application (Jorba & Sanmartí, 1994).

During the *exploration phase*, the tutor needs to get information on the baseline situation and, above all, learners have to understand where they are going and why.

In the *introduction phase*, there is a collaborative elaboration of the new concepts presented by the tutor or one of the learners.

In the *restructuring phase*, collaborative work helps in consolidating newly constructed content. This is the moment where the new content (in this case, a new conception of energy degradation concept) is rebuilt, "metabolised."

In the *application phase*, content learned through a given situation is generalized to other contexts.

We do not think of the learning cycle as a mechanistic procedure for sequencing learning activities, but rather as a useful framework within which to organize teaching sequences.

THE TEACHER EDUCATION PROPOSAL

In accordance with the framework described above, we designed a teacher education program in the shape of a workshop entitled "Teaching about Energy Degradation" (Pintó, Gutierrez, & Couso, 2000). It is focused on overcoming the problems that we interpreted as the main reasons for the existence of the alternative conceptions detected:

- Teachers' difficulties when dealing with scientific concepts that are unusual in their teaching (such as energy degradation)
- Teachers' lack of accuracy in using new, scientifically adequate language of the innovation, or lack of awareness of the importance of doing so.

Since we give great importance to correct use of language as a way of expressing scientific ideas effectively, the workshop is designed to encourage reflection on the use of scientific language associated with the concept of energy degradation (Pinto, Gutierrez, & Couso, 2001). We agree with Mortimer and Machado (2000), when they observe that

> The recognition, by the teachers, of the role of language and of the discursive interactions in the process of elaboration of scientific concepts has been one of the most important conditions in making possible changes in teaching practice. (p. 440)

A description of the activities that correspond to each of the phases of the learning cycle follows. Figure 2 gives a summary of each of these activities, along with its place in the phases of the cycle.

Exploratory Phase

In the *exploratory phase*, three different activities are introduced.

Presentation of a Problematic Situation. We present the teachers with a challenging teaching situation, to be discussed. Its purpose is to encourage their interest in and motivation for teaching the topic of energy degradation. During an introductory activity where teachers talk, in collaborative groups of three or four, about their own experience in teaching energy, they are invited to discuss the following: "What is the scientific understanding

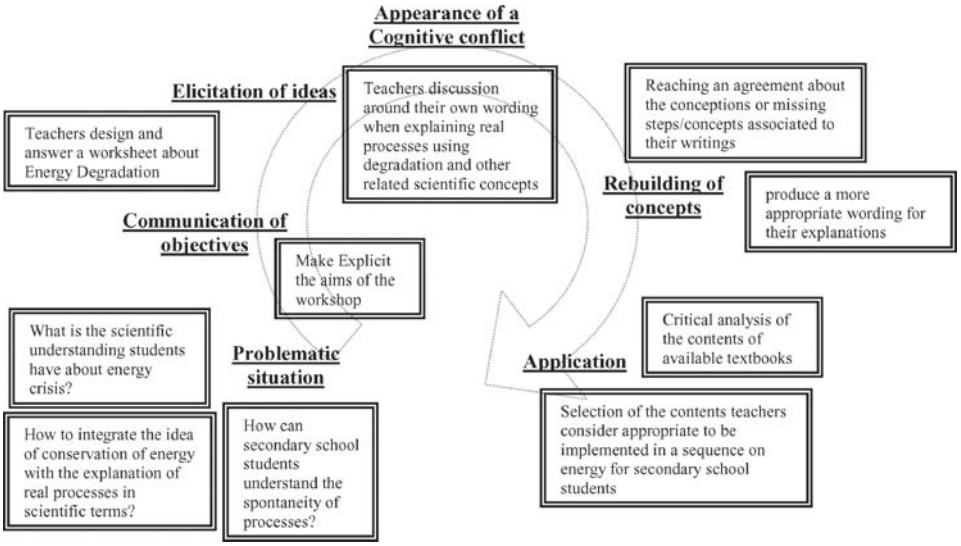


Figure 2. Overview of the activities of the teacher education proposal and their correspondence with the phases of the proposed learning cycle.

students have about the energy crisis? How can they integrate the idea of energy conservation with the explanation of real processes? How can secondary school students understand the spontaneity of processes?"

The teachers also need to feel the need to adopt the innovation. Black and Atkin (1996) stated that for the adoption of an innovation it is necessary first to create:

> [. . .] a perception that current practices and policies cannot help you to achieve whatever are your current educational goals. If that perception does not exists, and then any voluntary project will first have to create it. (p. 146)

In our present case, this perception will be that of the need to solve an apparent contradiction between common language (energy lost/used up) and scientific language (energy conservation) thus justifying the introduction of the energy degradation concept as part of the energy syllabus.

Communication of the Teacher Trainer's Aims. Having chosen a metacognitive perspective on conceptual change, we want the teachers to become aware of their own thought processes, difficulties, and progress when learning. Change can only be achieved by their own reflection on *where are they* and *where it is necessary for them to go*. Thus we stress the importance of the communication of the overall objectives of the workshop, that is, to tell teachers what is expected from them, together with the aims for each activity. Developing a first representation of the *game they are going to play* can activate appropriate mechanisms for the work that is to come. In the workshop, teachers are told that by the end they will be expected to

- be aware of the advantages of introducing the concept of energy degradation in teaching energy;
- realize the difficulties associated with the introduction of the energy degradation concept in the verbal explanations of real physical processes;

- note that, in their own discourse, explanations implying conceptions different from accepted ones can be seen, and to realize, therefore, the importance of using accurate language and wording in scientific teaching contexts.
- master the use of the concept of energy degradation in their explanations of specific and real processes using scientifically accurate terms.
- be able to critically analyze school materials commonly used for teaching energy.

Elicitation of Teachers' Conceptions of the Proposed Problematic Situation. In order to be able to address teachers' difficulties in their use of scientific language associated with the concept of energy degradation, the teacher trainer has first to be able to detect these difficulties. To achieve this, each of the collaborative teacher groups will be asked to design in common a worksheet as an introductory activity for teachers to present the concept of energy degradation to their students at secondary school. The worksheet should include questions to encourage a proper explanation of real everyday situations or processes using energy and related concepts. Some model worksheets are available to be used if desired: an example is one on the process of a wall being perforated using an electric drill.

After each group of teachers has produced their worksheets, they are asked to write scientifically correct answers for them. That is, the teachers have to answer the questions they have posed for their students in such way that other teachers consider them satisfactory from a scientific point of view. Each group of teachers, after discussing their answers and reaching a consensus, presents them in writing to the teacher trainer. In this way, alternative conceptions about energy and energy degradation are elicited.

The teacher trainer will need some time between workshop sessions to analyze the responses in order to obtain a spectrum of conceptions and forms of words about energy degradation. Help is provided, such as

- examples of answers teachers might give to the questions posed in the worksheet. These examples draw on the research of the Spanish STTIS team (Pintó & Gómez, 1999).
- a table including examples of quotes from teachers' discourse about energy degradation, possible alternative conceptions that can be associated with the quotes and a model of more adequate wording. This table again uses real quotes taken from the Spanish STTIS research. The table also includes some theoretical notes to help the teacher trainer to understand how the alternative conceptions can be inferred from the discourse. Table 2 is an extract from this table.
- guidelines for handling the material generated, for presentation back to the teachers in the workshop.

This analysis of teachers' answers will allow the teacher trainer to produce a table showing selected quotes from what they have written, the conceptions associated with them and a possible more adequate wording for them. Once the analysis is finished, the second main task can start.

Introduction of New Content: Bringing Cognitive Conflict to the Surface

This phase is the place for the discussion of conceptions and the presentation of new scientific language (here about energy degradation). It is where the possible unsuitability of teachers' alternative conceptions is evidenced, in other words, where cognitive conflict

TABLE 2
Quotes from Teachers' Discourse About Energy Degradation, Possible Alternative Conceptions That Can Be Associated with the Quotes, and a Model for More Adequate Wording

Prototypical Quotes	Conceptions as They Are Made Explicit	More Adequate Wording for the Quotes
"If the environment is part of the system, then energy is conserved. However if the environment does not make part of the system, then energy is degraded and dispersed"	It could be interpreted as understanding degradation of energy as opposite to energy conservation. *Supplementary notes for teacher trainers* Some teachers seem to consider that the energy only degrades when it is not conserved. From STTIS research results, it is not possible to assure if teachers interpret that energy degrades when it goes out of the system or that we can only talk about energy degradation when we refer to open systems. Any case, degradation is not linked to any capacity to do useful work, to a loss of quality, but rather to energy quantity. The meaning of energy degradation has become restricted or distorted. It reminds the idea that only one thing, degradation or conservation, can take place at the same time.	"If the environment is taken as part of the system, the system is isolated and then, energy is conserved. However if we do not consider the environment as part of the system, then energy it is not conserved in this open system. However, along a real process there is a degradation of energy in both cases: energy is dispersed, losing concentration and capacity to do work" *Supplementary notes for teacher trainers* Energy is always conserved in an isolated system. This does not mean that it cannot be degraded. There is the same energy at the beginning than at the end of a process occurring in an isolated system, but the energy at the end is less useful, it has lost quality but not quantity. Conservation and degradation of energy are not opposite concepts.

should appear, leading to a "change of status" of previous conceptions (Hewson & Hennesey, 1992). The new conceptions presented have to be seen as being more appropriate for teaching. The role of the teacher trainer in facilitating and orienting this discussion is a key factor for allowing teachers' cognitive conflict to appear.

Evidently, although we are here presenting successive phases in a learning cycle, there can be no sharp sequencing in time for each step. For example, during the design of a worksheet and discussion in collaborative groups, usually in a relaxed atmosphere, teachers are faced with different points of view. Negotiations within the group for an acceptable completion of the worksheet may well help to destabilize their previous conceptions, making room for cognitive conflict to occur in the so-called exploration phase.

At the start of this second session, the whole group of teachers is shown the selected quotes from their own writings. The teacher trainer guides a discussion with the aim of encouraging teachers' awareness of the conceptions implied by their own discourse. For some teachers, this is the moment where cognitive conflict arises. The teacher trainer plays the role of "catalyst" throughout this process where teachers reflect upon their own wording, realizing the inaccuracy, from the point of view of the innovation, of some of their statements.

Once teachers are able to critically analyze their own answers and those of their peers and to detect the possible conceptions that they reveal (or at least become aware that they exist), the teacher trainer starts a discussion about more adequate rewordings for these quotes. For teachers who may have made an unrefined use of the terms, through lack of disciplinary knowledge, being asked to reformulate their wordings will be an indirect way of introducing the scientific view, and to be provided with the means for achieving conceptual change. We believe that teachers can learn an innovatory language through the reflective and social process of reformulating their own explanations, their own discourse (Gutierrez, 2003).

The scheme of writing the worksheets first and rewording the statements later derives from the rather low level of awareness that we often have of the terms that we use in our everyday speech, unless there is a special sensitivity to careless use of language.

Restructuring Phase

The use of careless language is often the result of teachers' wish to express themselves in the most comprehensible way possible for their students, without having realized the consequences that this can have. The need for care in the use of language and, at the same time, the need to be understood, have to be brought into some kind of balance, and this is not an easy thing to do. Whilst teachers, from their professional experience, tend generally to have adapted their discourse to their students, they do not always notice the way in which ideas have been reformulated in this process. For this reason, for the "metabolisation" of the new language needed to discuss energy degradation, it is suggested that many diverse "quotes" are reformulated. The teacher trainer may wish to propose the "new" language for other expressions that may not have appeared in the quotes, but which teachers know of, having heard of them in the media, for example.

It must be made clear that, though in these activities teachers learn how to avoid such phrases as "energy has been lost" or "energy is used up in the process," this does not mean that in different contexts these cannot be used. As we mentioned previously, both everyday and scientific explanations can coexist. When, for example, the mass media talk of the energy crisis, a scientifically literate citizen will understand that the energy availability of important energetic resources has decreased. It is very valuable to understand the scientific meaning of these "rough" words or expressions. Indeed, establishing a "solid bridge" between the scientific world and the everyday world is an essential part of increasing the scientific literacy of our population.

Application Phase

The purpose of the final, application, phase is that learners become able to generalize the use of new ideas to new situations. Like Harlen (2000), we could say that, in order to reach the end of the learning process, it is necessary that processes of transformation and categorization of new ideas taught take place. For this purpose, it is appropriate to provide new problems to solve, with which a new learning cycle opens up.

At this point in the workshop the teachers are asked to use, in new concrete and real situations, what has been learnt. For instance, they are asked to critically review the materials they usually use for teaching energy.

Materials

Materials developed to support the training workshops include didactical guidelines, didactical resources and worksheets, all of them available in the project URL (Pintó, Gutierrez, & Couso, 2000).

FINAL REMARKS

In this paper, we have attempted to show one way in which to articulate a teacher-education program in order to confront certain transforming tendencies that can diminish the potential of proposed innovations, in particular transformations observed in teacher's discourse that may give rise to conceptual misunderstandings in their students.

The transformations observed when researching curricular reforms of this kind show how the steps usually taken, at least in our country, to introduce an innovative teaching sequence (innovation designers draw up suitable materials, design didactical orientations, and give spoken presentations) are not sufficient for teachers to make such an innovation their "own," in spite of their interest in and agreement with it.

In this sense, our teacher education proposal aims to help teachers reflect on the transformations that they unavoidably make when putting an innovation into practice, according to their own knowledge, beliefs, and context of work. Through the analysis of their own activity, here their discourse when teaching energy degradation in a teaching situation analogous to their own, teachers reflect on their transformations and the implications of these for students learning. We consider this an important first step for teachers to help them recognize their transformative role in the innovation process, which could aid them in the future to address innovations in a more critical and detailed way.

In designing the training workshop we have kept in mind a perspective that goes well beyond the particular case in hand — a workshop on ideas of energy degradation. We hope to have suggested the basis on which more *generalizable* learning habits can be sustained: reflective practice, discussion among colleagues, critical analysis, metacognitive perspective, etc. Our organization of the activities in a learning cycle should not be interpreted as a "recipe" that says exactly what to do at each moment. Our aim is simply to show in a practical manner how the theoretical framework for the teaching and learning that we have chosen can be applied to design and organize the activities for a workshop.

A single, short workshop, will of course have little impact on getting teachers to internalize all these features at once. We agree with Fullan (2001) that

> professional development is not about workshops and courses; rather, it is at it's heart the development of habits of learning that are far more likely to be powerful if they present themselves day after day. (p. 253)

However, where no other longer-term professional development structures are available, we rely on our teachers' willingness to discuss innovations, to reflect on their practice and discourse, to interact with others and to learn in this process. We also rely on their ability to change their practice, and to adopt innovations with a greater sense of control and ownership after having the opportunity to experience the success of these methodologies. This particular workshop aims to be precisely that a successful opportunity for teachers.

REFERENCES

Ametller, J., & Pintó, R. (2001). Teachers transformations of images representing the concept of system and environment. In D. Psillos, P. Kariotoglou, V. Tselfes, G. Bisdikian, G. Fassoulopous, E. Hatzikraniotis, & M. Kallery (Eds.), Proceedings of Third International ESERA Conference on Science Education Research in the Knowledge Based Society (pp. 270–272) . Thessaloniki, Greece: Art of Text.

Anderson, T., Howe, C., & Tolmie, A. (1996). Interaction and mental models of physics phenomena: Evidence from dialogues between learners. In J. Oakhill & A. Garnham (Eds.), Mental models in cognitive science. Essays in honour of Phil Johnson-Laird (pp. 247–273). East Sussex, UK: Psychology Press.

Arnold, M., & Millar, R. (1996). Learning the scientific "story": A case study in the teaching and learning of elementary thermodynamics. Science Education, 80(3), 249–281.

Arons, A. B. (1999). Development of energy concepts in introductory physics courses. American Journal of Physics, 67, 1063–1067.

Atkins, P. W. (1994). The second law. New York: Scientific American Books.

Bécu-Robinault, K., & Tiberghien, A. (1998). Integrating experiments into teaching of energy. International Journal of Science Education, 20(1), 99–14.

Beeth, M. E., & Hewson, P. W. (1999). Learning goals in an exemplary science teacher's practice: Cognitive and social factors in teaching for conceptual change. Science Education, 83(6), 738–760.

Black, P., & Atkin, J. M. (Eds.). (1996). Changing the subject: Innovations in science, mathematics and technology education. London: Routledge.

Boohan, R., & Ogborn, J. (1996). Differences, energy and change: A simple approach through pictures. School Science Review, 78(283), 13–19.

Cárdenas, M., & Ragout, S. (1996). Explicaciones de procesos termodinámicos a partir del modelo corpuscular: Una propuesta didáctica. Enseñanza de las Ciencias, 14(3), 343–349.

Chevallard, Y. (1985). La transposition didactique. Grenoble, France: La Pensée.

De Jong, O., Korthagen, F., & Wubbels, T. (1998). Research on science teacher education in Europe: Teacher thinking and conceptual change. In B. J. Fraser & K. J. Tobin (Eds.), International handbook of science education (pp. 745–758). London: Kluwer.

Domenech, J. L. (2000). L'ensenyament de la energia en l'educació secundària. Anàlisi de les dificultats i una proposta de millora. PhD thesis. Universitat de Valencia, Spain.

Driver, R., & Millar, R. (Eds). (1985). Energy matters. Leeds, UK: Centre for Science and Mathematics Education, University of Leeds.

Duit, R. (1981). Understanding energy as a conserved quantity. European Journal of Science Education, 3(3), 291–301.

Duit, R. (1983). Is the second law of thermodynamics easier to understand than the first law? In G. Marx (Ed.), Entropy in the school: Proceedings of the 6th Danube Seminar on Physics Education (pp. 87–97). Budapest: Roland Eötvös Society.

Duit, R. (1987). Should energy be illustrated as something quasi-material?. International Journal of Science Education, 9(2), 139–145.

Duit, R., & Haussler, P. (1983). Some ideas for dealing with energy degradation in grades 5 to 10. In G. Marx (Ed.), Entropy in the school: Proceedings of the 6th Danube Seminar on Physics Education (pp. 388–396). Budapest: Roland Eötvös Society.

Duschl, R. A. (1994). Beyond cognition: The epistemic and social challenges of conceptual change teaching. Lecture presented in the IV Congreso Internacional sobre investigación en Didáctica de las Ciencias y de las Matemáticas. Barcelona: ICE de la UAB.

Fensham, P. J., Gunstone, R. F. & White, R. T. (Eds.). (1994). The content of science: A constructivistic approach to its teaching and learning. London: Falmer.

Fullan, M. (2001). The new meaning of educational change. New York: Teachers College Press.

Gallagher, J. (1991). Prospective and practicing secondary school science teachers' knowledge and beliefs about the philosophy of science. Science Education, 75(1), 121–133.

Geddis, A. N. (1991). Improving the quality of science classroom discourse on controversial issues. Science Education, 75(2), 169–183.

Goldring, H., & Osborne, J. (1994). Student's difficulties with energy and related concepts. Physics Education, 29, 26–31.

Gutierrez, R. (2003). Conversation theory and self-learning. In D. Psillos, P. Kariotoglou, V. Tselfes, G. Bisdikian, G. Fassoulopous, E. Hatzikraniotis, & M. Kallery (Eds.), Science education research in the knowledge-based society (pp. 43–49). Dordrecht: Kluwer.

Harlen, W. (2000). Teaching, learning and assessing science 5–12. London: Paul Chapman Publishing.

Hewson, P. W. (1993). El cambio conceptual en la enseñanza de las ciencias y la formación de los profesores. In C. Palacios, D. Ansoaga, & A. Ajo (Eds.), Diez años de investigación e innovación en enseñanza de las ciencias: CIDE 1983–1993 (pp. 331–351). Madrid: CIDE-MEC.

Hewson, P. W., & Hennesey, M. G. (1992). Making status explicit: A case study of conceptual change. In R. Duit, F. Goldberg, & H. Niedderer (Eds.), Research in physics learning: Theoretical issues and empirical studies (pp. 176–187). Kiel, Germany: IPN.

Hewson, P. W., Tabachnick, B. R., Zeichner, K. M., Blomker, K. B., Meyer, H., Lembeger, J., Marion, R., Park, H., & Toolin, R. (1999). Educating prospective teachers of biology: Introduction and research methods. Science Education, 83(3), 247–273.

Hewson, P. W., Zeichner, K. M., Tabachnick, B. R., Blomker, K. B., & Toolin, R. (1992). A conceptual change approach to science teacher education at the university of Wisconsin-Madison. Lecture presented in the Annual Meeting of the American Educational Research Association, San Francisco, CA.

Hicks, N. (1983). Energy is the capacity to do work—or is it? The Physics Teacher, 21(15), 529–530.
Huibregtse, I., Korthagen, F. A. J., & Wubbels, T. (1994). Physics teachers' conceptions of learning, teaching and professional development. International Journal of Science Education, 16(5), 539–561.
Johnston, K. (1991). High school science teachers' conceptualisations of teaching and learning: Theory and practice. European Journal of Teacher Education, 14(1), 65–78.
Jorba, J., & Sanmartí, N. (1994). Enseñar, aprender y evaluar. Un proceso de regulación continuo: Propuestas didácticas para las áreas de ciencias naturales y matemáticas. MEC, Madrid. Photocopied document.
Kaper, W. H., & Goedhart, M. J. (2002). "Forms of energy," an intermediary language on the road to thermodynamics? Part 1. International Journal of Science Education, 24(1), 81–95.
Karplus, R. (1977). Science teaching and the development of reasoning. Journal of Research in Science Teaching, 14(2), 169–175.
Karplus, R., & Lawson, A. E. (1974). Science teacher's handbook. Berkeley, CA: University of California.
Kesidou, S., & Duit, R. (1993). Students' conceptions of basic ideas of the second law of thermodynamics. Journal of Research in Science Teaching, 29, 85–106.
Lawson, A. E., & Wollman, W. T. (1976). Encouraging transition from concrete to formal cognitive functioning—an experiment. Journal of Research in Science Teaching, 13(5), 413–430.
Lederman, N. (1992). Students and teachers' conceptions of the nature of science: A review of research. Journal of Research in Science Teaching, 29(4), 331–359.
Linder, C. J. (1992). Is teacher-reflected epistemology a source of conceptual difficulty in physics? International Journal of Science Education, 14(1), 111–121.
L'Oughlin, M. (1992). Rethinking science education: Beyond piagetian constructivism toward a sociocultural model of teaching and learning. Journal of Research in Science Teaching, 29(8), 791–820.
Martinez, J. M., & Perez, B. A. (1997). Estudio de propuestas alternativas en la enseñanza de la termodinámica básica. Enseñanza de las Ciencias, 15(3), 287–300.
Moje, E. B. (1995). Talking about science: An interpretation of the effects of teacher talk in a high school science classroom. Journal of Research in Science Teaching, 32(4), 349–371.
Mortimer, E. F., & Machado, A. H. (2000). Anomalies and conflicts in classroom discourse. Science Education, 84(4), 429–444.
Ogborn, J. (1983). Approaches to teaching thermodynamics. In G. Marx (Ed.), Entropy in the school: Proceedings of the 6th Danube Seminar on Physics Education (pp. 476–479). Budapest: Roland Eötvös Society.
Ogborn, J. (1986). Energy and fuel: The meaning of "the go of things." School Science Review, 68, 30–35.
Ogborn, J. (1990). Energy, change, difference and danger. School Science Review, 72, 81–85.
Pintó, R. (1993). Algunos conceptos implícitos en la 1ª y la 2ª leyes de la termodinámica: Una aportación al estudio de las dificultades de su aprendizaje. PhD thesis. Bellaterra, Spain: Publicacions de la Universitat Autònoma de Barcelona.
Pintó, R. (2005). Introducing curriculum innovations in science: Identifying teachers' transformations and the design of related teacher education. Science Education, 89, 1–12.
Pintó, R., & Gómez, R. (1999). Teaching about energy in Spanish secondary schools: Teachers' transformations of innovations. STTIS Spanish National Report on WP3. Universitat Autònoma de Barcelona [online]. Available at: http://www.blues.uab.es/∼idmc42/
Pintó, R., Gutierrez, R. Ametller, J., Andresen, O., Balzano, E., Boohan, R., Chauvet, F., Colin, P., Couso, D., Giberti, G., Hirn, C., Kolsto, S. D., Monroy, G., Ogborn, J., Quale, A., Rebmann, G., Sassi, E., Stylianidou, F., Testa, I., & Viennot, L. (2001). Teachers transformations trends when implementing innovations. STTIS Report RW4 [online]. Retrieved March 15, 2003, from http://www.blues.uab.es/∼idmc42
Pintó, R., Gutierrez, R., & Couso, D. (2000). Teaching about energy degradation. Universitat Autònoma de Barcelona [online]. Retrieved March 15, 2003, from http://www.blues.uab.es/∼idmc42
Pintó, R., Gutierrez, R., & Couso, D. (2001). Teaching about energy conservation and degradation. Using research into teachers' transformations to design material for teacher training. In D. Psillos, P. Kariotoglou, V. Tselfes, G. Bisdikian, G. Fassoulopous, E. Hatzikraniotis, & M. Kallery (Eds.), Proceedings of Third International ESERA Conference on Science Education Research in the Knowledge Based Society (pp. 152–155). Thessaloniki, Greece: Art of Text.
Renner, J. W., & Lawson, A. E. (1973). Promoting intellectual development through science teaching. Physics Teacher, 11(5), 273–276.
Ross, K. A. (1988). Matter scatter and energy anarchy: The second law of thermodynamics is simply common experience. School Science Review, 69(248), 438–450.
Saltiel, E. (1997). Le principe de conservation de l'énergie et le théorème de l'énergie mécanique en classe de première. Bulletin de l'union des Physiciens, 91, 957–972.
Sanchez, G., & Valcarcel, M. V. (2000). Relación entre el conocimiento científico y el conocimiento didáctico del contenido: Un problema en la formación inicial del profesor de secundaria. Alambique, 24, 78–86.

Sassi, E., Monroy, G., & Testa, I. (2001). Research-based teacher training about real-time approaches: Some guidelines and materials. In D. Psillos, P. Kariotoglou, V. Tselfes, G. Bisdikian, G. Fassoulopous, E. Hatzikraniotis, & M. Kallery (Eds.), Proceedings of Third International ESERA Conference on Science Education Research in the Knowledge Based Society (pp. 156–158). Thessaloniki, Greece: Art of Text.

Schoon, K. J., & Boone, W. J. (1998). Self-efficacy and alternative conceptions of science pre-service elementary teachers. Science Education, 82(5), 553–568.

Sciarretta, M. R., Stilli, R., & Vicentini, M. (1990). On thermal properties of materials: Common-sense knowledge of Italian students and teachers. International Journal of Science Education, 17(5), 621–634.

Smit, J. J. A., & Finegold, M. (1995). Models in physics: Perceptions held final-year prospective physical science teachers studying at South African universities. International Journal of Science Education, 17(5), 621–634.

Solbes, J., & Tarín, F. (1998). Algunas dificultades en torno a la conservación de la energía. Enseñanza de las Ciencias, 16(3), 387–397.

Solomon, J. (1982). How children learn about energy or does the first law come first? School Science Review, March 1982, 415–422.

Solomon, J. (1985). Teaching energy conservation. Physics Education, 20, 165–167.

Solomon, J. (1987). Energy—The ghost in the body. School Science Review, 68(245), 635–644.

Strömdahl, H., Tüllberg, A., & Lybeck, L. (1994). The qualitatively different conceptions of 1 mol. International Journal of Science Education, 16(1), 17–26.

Summers, M., & Kruger, C. (1994). A longitudinal study of a constructivist approach to improving primary teachers' subject matter knowledge in science. Teaching and Teaching Education, 10, 499–519.

Thorley, R. N., & Stofflett, R. T. (1996). Representation of the conceptual change model in science teacher education. Science Education, 80(3), 317–339.

Tiberghien, A. (1996). Energy teaching at high school level: A challenge? In M. Michelini, S. Pugliese, & D. Cobai (Eds.), Teaching the science of condensed matter and new materials (pp. 95–105). Udine, Italy: FORUM.

Trumper, R. (1993). Children's energy concepts: A cross-age study. International Journal of Science Education, 15(2), 139–148.

Van Huis, C., & Van Der Berg, E. (1993). Teaching energy: A systems approach. Physics Education, 28, 146–153.

Vicentini, M., & Mayer, M. (1996). Didattica della fisica. Firenze: La nuova Italia.

Viglietta, L. (1990). A more "efficient" approach to energy teaching. International Journal of Science Education, 12(5), 491–500.

Wiser, M., & Amin, T. (2001). "Is heat hot?" Inducing conceptual change by integrating everyday and scientific perspective on thermal phenomena. Learning and Instruction, 11, 331–355.

Zuzovsky, R. (1994). Conceptualizing a teaching experience on the development of the idea of evolution: An epistemological approach to the education of science teacher. Journal of Research in Science Teaching, 31(5), 557–574.

6. Publication 2

Teachers' Collaborative Reflections about School-Based Science Innovation.

Publication 2 of this compendium reports the results of the research **Project EUDIST** (European Development of Innovative Science Teaching), funded by the European Commission, DG Education and Culture, within the Socrates Comenius Programme 2.1. Ref: 106278-CP-1-2002-1-DE-COMENIUS-C21, from 2002-2005.

EUDIST was a project of research and development that emphasises the importance of school-based teacher professional development grounded on collaboration, reflection and feedback. In each country, pilot schools were purposefully selected, referred to as school-based collaboratives, according to pre-defined criteria for effective teacher education and curriculum practice in science education. In addition to the documentation of each of these cases of school-based development, within EUDIST participating teachers from different schools and national coordinators meet in a national Curriculum Workshop to exchange their experiences and deliberate on examples of good practice in school-based teacher education, curriculum design and school development. The CW scenario allows teachers to play an active role in a school-based discourse about experiences, purposes and ends of their work, implying a conception of democracy that emphasises discursive decision making of teachers and schools (Lang 2007). The CW's of EUDIST were conducted in several steps during the first months of 2004. Out of these opportunities of collaborative reflection, deliberation, exchange and discussion, participating teachers generated practical outcomes for feedback. A national case study was elaborated by each coordinator to describe, analyse and interpret the whole experience, documenting teachers' participation in different types of school-based innovation and in the CW series.

The Publication 2 included in this compendium is the published version of the Spanish case study within EUDIST. In the Spanish EUDIST project, teachers' reflections about the process of implementing innovations in science education at school have been supported and documented. Initial case-studies were conducted in four different schools around Barcelona where innovations in science teaching were

implemented. The originators and supporters of each innovation (educational researchers, teacher leaders or teachers themselves) responded to semi-structured interviews about: rationale, aims and expectations of the innovation; how the innovation was implemented and what kind of teacher preparation/support was offered. The deliberations and discussions of a representation of teachers per participating school during the CW's were video-recorded to analyse teachers' discourse. Other documents, such as teachers' narratives, the outcome documents from the CW, and a post-CW feedback questionnaire were used develop the national case study. Out of this study, teachers' perceptions of school-base innovation in Spain were found.

Regarding the research problem of this thesis, Publication 2 analyses briefly the particular school-based innovation scenarios of each of the participating schools to discuss to what extend they are effective professional development scenarios. In addition, Publications 2 analyses in bigger detail to what extend the particular design of the Spanish CW, adapted to this context, is in itself an interesting professional development scenario related to school-based innovation. In these settings, teachers' participate in identity formation, reflect collaboratively and evidence empowerment.

Chapter 3: Teachers' collaborative reflections about school-based science innovation in Spain.

Digna Couso and Roser Pintó

Introduction to EUDIST in Spain: teachers involved in innovations constructing their own voice

School-based reform demands from teachers that they originate, design, lead, participate actively, reflect on and be critical of school reform. This scenario challenges the professionalism of teachers in new ways. Knowledge about the school-based reform process is necessary for these teachers to guide future practice, but also for educational policy-making and professional development design that support this bottom-up approach. This knowledge is embedded in the practice of the "innovative" teachers who are currently struggling with school-based reform.

To help disembody this knowledge, the Spanish EUDIST project involves teachers and teacher leaders from schools where school-based reform is taking place and engages them in a collaborative reflective dialogue about school-based innovation: the Curriculum Workshop. The outcome is a collaboratively constructed "innovative" teachers' voice focusing on the questions of what motivates school-based reform, what changes during the process and how this process can be effectively supported.

Apart from being a knowledge-construction scenario, the Curriculum Workshop in Spain has also a professional development dimension aiming to promote participating teachers' networking and collaboration, reflection, deliberation and empowerment. Four metaphors for the teacher in school-based reform directed this approach: the teacher as a knowledgeable agent; as a social agent in a community of practice; as a reflective agent and as an impelling-reform agent.

The notion of teachers and schools at the core of curriculum reform, described in the literature with metaphors such as *teachers as curriculum makers* (Calgren 1999) and *schools as knowledge creating institutions* (Hargreaves 1999), is central to the EUDIST rationale. It is central to EUDIST also the intention to address both processes from a democratic approach, supporting the creation of a school culture of equality, collaboration and deliberation among different educational stakeholders. EUDIST in Spain stems from this conception of school-based reform and looks for successful examples of curriculum innovation initiatives in Spanish schools that align with its rationale and approach.

The aim of the EUDIST project in Spain is supporting teachers to construct collaboratively their reflective voice about the process of bottom-up curriculum innovation. The construction of the voice of these "innovative" teachers in Spain is the construction of the perceptions of teachers who struggle with school-based curriculum innovation in a permissive, but not particularly encouraging, scenario. Our interest in their voice is twofold. From the educational research viewpoint, the "innovative"[1] teachers' voice captures the perceptions of experienced agents of bottom-up reform, which can offer new insights to guide future action. From a teacher education perspective, the process of construction of their voice in a scenario where networking and collaborative reflection is promoted becomes a professional development experience for the participating teachers.

The Curriculum Workshop (CW) approach, introduced previously in this book, is used in the EUDIST Spanish project to support this construction process. Within the framework of the CW in Spain, teachers discuss the facilitating and constraining factors involved in putting into practice bottom-up innovations in their schools; they reflect about their experience and how they face the challenge; they discuss what they consider would support these initiatives and propose recommendations for future actions.

In the next paragraphs, the process of construction of the "innovative" teachers' voice (regarding school-based science innovation) that took place in the EUDIST project in Spain is described. To begin with, the Spanish educational context and the characteristics of the Spanish participating schools and innovations are introduced.

The Spanish Context in EUDIST: heaven or hell for school-based innovation initiatives?

There are many differences among educational systems across Europe, which implies that there are different scenarios for school-based reform. Characterising these scenarios as they affect school-based curriculum innovation implies more than characterising their curriculum. Due to the fact that school-based innovation is bottom-up in approach and aims to have a school dimension, it poses a great challenge both to teachers and schools (as institutions). Therefore, all aspects of school organisation and teacher professionalism have an impact in school-based reform. Aspects such as teachers' education (the usual pre and in-service training that teachers receive); teacher career prospects (the usual path teachers take in their careers, how long they stay in teaching); teachers' autonomy (the degree of freedom and

responsibility teachers have for the different curricular decisions to be made); school micro-politics (the power relationships within the school hierarchical structure), etc. set up very different scenarios among different schools across different countries. Some of these scenarios are more favourable to school-based curriculum innovation than others.

Characterizing the Spanish school in the wider way mentioned before is, in this sense, crucial for understanding the context in which school-based reform takes place in Spain. In Table 1 a short description of the most important aspects of the Spanish educational system has been attempted.

The educational scenario described in Table 1 for the Spanish school is that of a school which suffers from a contradictory situation regarding school-based innovation. Under the umbrella of a broad official syllabus, curriculum definition is expected to occur at the school level, allowing schools and teachers enough freedom and autonomy in the innovation of their teaching. However, the lack of an effective school structure (some capacity of decision-making for teacher leaders) and of a culture of collaboration, in particular in the secondary school with subject-specific teacher profiles, makes it difficult for most of this curriculum innovation to have real "school dimension". In this sense, the general profile of curriculum development in Spain is narrow in scope and very individualistic. In other words: a lot of innovation is done but too often occurs inside the particular classroom or among little groups of teachers, having less impact than desirable in the global teaching and learning of the students of a particular school.

Curriculum decision-making	**Curriculum structured in three levels of concreteness:** The first level is a broad syllabus established by the regional/national educational authorities. It includes a list of contents for a 2-year period of schooling for every subject and the list of learning outcomes[2] to be achieved. The second level is asked to be prepared by schools, and it is a deeper curriculum definition based on these broad official guidelines. This work is generally done by teachers in the corresponding subject departments. The deepest level of concreteness of the curriculum is the actual teaching unit, done generally at the teachers' level. Despite some innovative teachers who select, design and/or prepare most of their teaching materials, the majority of teachers rely mainly on textbooks for this purpose.

Science curricula	In **primary school Science it is taught in an integrated way** in the subject "Knowledge of the natural environment". **In lower and upper compulsory secondary school**, science is taught in an apparently integrated way, including biological, geological, physical and chemical contents in the subject "Natural Sciences". However, due to the fact that secondary school teachers are specialised either in biology/geology or physics/chemistry, the implementation of the official curriculum of Natural Sciences **is generally structured so that biological and geological content is taught one year and physical/chemical content in the next one.**
General pedagogy	The Spanish school was subjected to a very deep organisational and pedagogical educational reform in the early nineties with the **LOGSE**[3] law. This reform changed fundamentally the organisation[4] and rationale of the secondary schooling system, which moved from being post-compulsory to compulsory until 16 years old. **This change in structure implied a comprehensive philosophy in compulsory secondary education** which set enormous challenges for teachers, in particular regarding the role of content, assessment, classroom management, etc.(See Black and Atkin, 1996, for an account on this national reform).
Teacher pre- and in-service education	**Primary school teachers are education graduates of the Education Faculty**, after three years of general education study (no specialisation in science[5]). **Secondary school teachers have a background of four years of study in a particular discipline** (physics, biology, history, language, etc.). After their graduation, they need pedagogical and didactical training to be eligible as teachers. There is a permanent offer of short-term in-service training and support for specific pedagogical and didactical topics. For particular school projects, there is also the possibility of having advisory support.
Teachers' careers	**Most teachers in the state school system are civil servants** after passing challenging official examinations both in content matter, specific didactics and general pedagogy. There is a very low drop-out rate from the teaching profession. There is a lack of promotional possibilities within the school (See school-micro politics). Instead, to progress, teaching staff combine teaching with other jobs outside the school as teacher advisors, within the Education Department, etc.

[3] Details of LOGSE can be found at:
http://www.boe.es/g/es/bases_datos/doc.php?coleccion=iberlex&id=1990/24172

[4] Details of the actual structure of the Spanish School System can be found in the URL: www.mec.es/educa/sistema-educativo/logse/siseduc.html

[5] Only primary school teachers of Music, Physical Education, Special Education and Foreign Language Education are educated as subject specialist in the Spanish present University System.

School micro politics	**Schools in Spain have a similar structure to schools in many other countries**, including headteacher, heads of department, heads of Key Stages, tutors, etc. However these positions, in particular for state schools, do not necessarily correspond to positions of real power for decision making at the school level. They are considered to be mainly administrative positions that imply different responsibilities and tasks, but have generally the same status and power as the rest of the teaching staff. In many schools these positions rotate among the teachers. Sometimes the higher professionalism of some teachers (for instance, holding a teaching professorship, being a teacher trainer, doing action research, etc.) is used for selecting heads of department and other roles in the school hierarchy. However, due to the fact that state teachers are not selected and contracted at the school level but at the state level, **in Spanish schools, teachers work in an almost *flat* hierarchical system.**

Table 1: Summary of main aspects of the Spanish educational system.

This situation of the Spanish educational system has implications for educational action. For instance, it is difficult to enrol a school in an educational project without enrolling the teachers of the school individually. This and other differences between the Spanish schools and most international educational systems can sometimes hinder making a cross-comparison. Just as an example, all the literature about the role of the principal or educational district administration in school settings has almost no meaning in the Spanish school context[6].

The establishment of partner schools in the Spanish context: selection of examples of school-based innovations

Despite not facilitating school-based reform, the presented scenario of the Spanish school allows for it. In this sense, some initiatives of school-based curriculum reform that accord with the EUDIST view can be found. These are schools were teachers' struggle to achieve collaborative and deliberative involvement, in general aiming for long-term and wide-scope curriculum change. The number of these initiatives is scarce, but what can be learnt from them is very interesting in order to understand how they can be promoted and supported in the Spanish context.

In selecting the sample adequate for the objectives of EUDIST in Spain, it was necessary to contact schools and teachers which were implementing[7]

[6] We are referring here to the state school system.

[7] There are different meanings associated with the idea of "implementation" of curriculum reform, some of them related with the vision of the teacher as a technician that puts in practice what others have decided and designed. Following Fullan (2001), "Implementation consists of the process of

innovations in their teaching of science in the direction of school-based reform. At the same time, we wanted our purposive sample to be representative of the Spanish "innovative" school, that is, to include the different types of organisation of school-based innovation that can be found in the Spanish context.

All of the initiatives selected had in common a bottom-up approach, being either originated and/or run by teacher leaders[8] or teachers with the support of external advisors. For those originators and/or supporters of the innovation[9], the initiatives in which they were participating were in close contact with educational research and teacher education, being inspired or supported by advisory or teacher professional development opportunities. They also measured the possible interest of their initiative in terms of teachers´ involvement, educational quality of the initiatives and expectations of long-term change, these two latter in reference to science education literature and students' results.

The schools selected were required also to represent the diverse reality of innovative schools in our context. The range of schools was selected according to the following criteria: who originates and who supports the innovation process; what is the scope of the innovation (what sort of change is expected) and what is the scale of the innovation (for how long and how many teachers are involved). Following these criteria, the selection process looked for innovations with different sources of origin and support; different depths of the innovation initiative and diverse impact.

Selected school-based innovations range from top-down (School A) to bottom-up (Schools B, C and D) in origin and from currently being run by teachers (Schools A, B and C) to having advisory support (School D). Innovation in

putting into practice an idea, program, set of activities and structures new to the people attempting or expecting to change. The change might be externally imposed or voluntarily sought; explicitly defined in detail in advance or develop an adapted incrementally through use; designed to be used uniformly or deliberatively planned so that users can make modifications according to their perceptions of the needs of the situation." (p.65) In this sense, implementation is for us a neutral work regarding the style of the reform, and here is used in the context of bottom up innovation, thus implying teachers putting in practice what they have decided and designed.

[8] There is an extensive amount of research into the topic of teacher leadership from which several different definitions emerge. In this study, we do not stick to one particular definition due to the fact that we understand leadership to have a different meaning in different school contexts (Wasley, 1991). However, some notions of teacher leadership that emerge from the Wasley study of teacher leaders' perception of their own role are meaningful for us: teacher leaders as having the ability "to share information and to influence others in matters related to curriculum and instruction"; "to go beyond the classroom to be current in research, and to be teaching advocates"; "to move forward toward a better system rather than simply supporting the existing system."

[9] Data taken from personal interviews of teacher leaders and teacher educators involved in the SBC's. The originators responded to semi-structured interviews about the rationale, aims and expectations of the innovation; how the innovation was implemented and what kind of teacher preparation/support was offered.

Schools C and D aimed at "superficial" changes in the sense of involving small modifications of current practice, whereas in Schools A and B innovations aimed at "revolutionary" changes in the teaching of science and the role of the teacher. Regarding impact, innovations with short-term and/or narrow-involvement (Schools B and C), to long-term and/or wide involvement in such changes (Schools A and D), were selected.

Profiles of the participating schools and the Science Innovations.

Initial case-studies were conducted in four different schools around Barcelona (Catalonia, Spain). The school profiles are briefly described in Table 2. The descriptions of the innovations that were taking place in each of the schools are included in the following paragraphs[10].

	Location / Types	**Size**			**Other characteristics**
		Stud.	Tea	Tea Sci	
School A	Urban, Barcelona city / Lower and upper compulsory 2ary Post-compulsory 2ary Vocational courses	500	50	11	Piloting school during the 90's reform. Heterogeneous (low-medium) socio-economic level of students.
School B	Urban, near Barcelona / Lower and upper com-pulsory 2ary Post-compulsory 2ary	400	40	6	Structured by the teachers as a especially democratic institution. Low socio-economic level of students. Large percentage of immigrant students.
School C	Urban, near Barcelona / Lower and upper com-pulsory 2ary Post-compulsory 2ary Vocational courses	700	68	6	Involved in transversal educational initiatives. Medium socio-economic level of students.
School D	Non-urban school / Primary School	230	14		"Green school" participating in various environmental projects. Medium-high socio-economic level of students.

[10] Data obtained from teachers, teacher leaders and/or teacher educators' interviews, school profile questionnaires, observation notes and documentation gathered during the school and teachers' visits.

Science innovation in School A: "Changing everything by changing assessment"

The innovation in the teaching and learning of science at School A had a top-down origin, being a pilot school for the national reform process of the 90's[11]. To monitor and help teachers during this process, educational authorities provided a year of in-service teacher education support, which was compulsory and planned inside the teachers´ timetable. School A started this program together with other schools of very similar profiles, but was one of the few that decided to continue once it finished being compulsory, having regular advisory visits during eight years from 1988. Despite being initiated at school level, only the science and mathematics departments decided to maintain the initiative and continued working with their supervisors[12].

Together with their advisors, the science and mathematics teachers of School A built a theoretical pedagogical and didactical framework around the topic of "Self-regulation of learning". The topic was not imposed on the teachers and, in fact, it was not a specific requirement of the national reform, but it came out as a result of the teachers and advisors collaborative work trying out different initiatives to meet the requirements of the new culture of comprehensive schooling. Teachers and educators focused on changing assessment, because "without changing the assessment, nothing would actually change" (teacher's quote). Changing from summative to formative assessment was much more demanding, in terms of teachers' time than traditional assessment. Teachers' realise they will not succeed without including the students actively in the innovation process to share "the weight" of the new assessment regime. In this sense, they decided to focus their strategy on promoting a change in the students' role towards that of a more autonomous, reflective and cooperative learner able to self and co-assess their work. Subsequently, the teachers' role also changed towards that of being the professional capable of providing the resources, learning situations and classroom management appropriate to promote students' self- and co-regulated learning processes.

During the innovation process, teachers and teacher educators elaborated a theoretical framework about this idea of self-regulation and its implementation into practice. Many publications at national level in teachers' journals, teachers' conferences and research journals emerged from this collaboration.

[11] See Table 1 for deeper description of the reform rationale.

[12] During the eight advisory years, School A had the same teacher educators, both of them university educational researchers specialising in Mathematics and Science Education, respectively.

Today, School A continues with the idea of promoting students self-regulation of learning as its main aim. Despite not having advisory in-service training since 1996, teachers mainly continue working within the innovation philosophy, introducing new-coming teachers when possible. Some pedagogical strategies, such as cooperative work of students, and some innovative didactical instruments such as concept maps, Gowing V´s, didactical contracts, etc., have now become usual. Other highly valued strategies, such as co-teaching, face more difficulties to survive in the school due to organizational timetabling problems. However, for teachers it is so enriching that they keep on changing some of their labwork sessions, officially organised among two teachers with half of the students each, to sessions with all the group of students with both teachers. In this sense, many of the strategies and tools developed in the context of the innovation are nowadays so deeply embedded in teachers' normal practice that they are not considered innovations any more in School A, despite teachers knowing these strategies are not used in general in other schools.

Survival of the innovation has relied mainly in the active role of teacher leaders A1 and A2, which have been in closest connection with the educational research field and particularly with their previous science advisor, with whom they continue working. Both these teachers engaged very actively in the innovation from the beginning (teacher A1, for instanced, changed from one school to School A when after the compulsory pilot year, her own school decided to abandon the advisory programme). They also have participated in numerous teacher education initiatives as teacher educators, both in Catalonia and other parts of Spain; they have published with their colleagues in teacher and research journals and participated in educational conferences. Recently, the education department of the regional government awarded them two sabbatical years to develop action research.

Science innovation in School B: "Science is Modelling"

The innovation taking place in school B was originated bottom-up, basically driven and supported by a particular teacher leader (B1), currently head of the science department of School B.

B1 is a teacher with extensive teaching experience, who from 1987 has been in close contact with research and teacher training institutions. Regarding curriculum innovation, teacher B1 participated actively, in collaboration with teachers from other schools and educational researchers at university, in the design of a challenging curriculum proposal called "Ciències 12-16". The main characteristic of this curriculum proposal was the view of teaching and learning of science as teaching and learning of scientific activity. The aim was replacing

the traditional "blackboard formula" science teaching by active observation and experimentation of phenomena directed towards science modelling. Both pedagogically and didactically "Ciències 12-16" was very innovative, focusing mainly in qualitative rather than quantitative work in science.

Initially, teachers in the science department of School B decided to adopt this proposed project, but it was seen as very demanding for most teachers and less convenient than the traditional textbook. During the course of 2001-02, B1 had a sabbatical year. During this time, he was asked to be an advisor for a fellow teacher with a biological background (B2) in order to assist in her teaching of some physics content. Apart from working together on classroom planning and selection of materials, both teachers engaged in co-teaching pupils. As a result of this activity, where his colleague could truly and supportively experience this new way of teaching science, both teachers started to collaborate closely in the adaptation and design of new materials following the 12-16 curriculum innovation rationale. Another colleague, who asked to be able to attend to some of their teaching sessions, also started to share their view. Both these teachers agreed that the new perspective allowed them to teach/deliver physics and chemistry classes in a more dynamic way. Unfortunately, the other three teachers in their science department did not engage so actively in this new philosophy for teaching science. For B1, this lack of full departmental involvement was due to the fact that it was too revolutionary a change without enough support, so a more conservative approach was needed.

Following teachers' decision last year to abandon the "Ciències 12-16" materials for a more convenient textbook, B1 suggested the reorganization of the curriculum plan to ensure that the textbook had a limited role (only as a tool instead of the main guideline). He took the official list of curriculum contents and learning outcomes to propose and discuss with his colleagues what could be an interesting exploratory, introductory and application activity for each of them, so that each theme would be taught following a learning cycle. This was done for teachers to realise more clearly the limitations of the book: when the book was not including some of the required activities, teachers had to use their own materials. This resulted in teachers suggesting as extra material many activities from the previous "Ciències 12-16" experience, the ones they had really liked, under the "safe" umbrella of the "textbook". However, the amount of time devoted to this exhaustive planning was mostly at B1's cost and the lack of involvement of some of these colleagues was somehow discouraging.

The expectation for future curriculum innovation in School B is for teachers to collaboratively design teaching and learning sequences, as described above, when these are missing from textbooks. By doing so, B1 would like to be able

to take into account the modelling perspective for science teaching that he is trying to promote in the department, which after the "Ciències 12-16" initiative is more well-known by his colleagues.

Science innovation in School C: "Learning to talk Science"

The innovation taking place in School C was originated bottom-up, and was basically driven and supported by a particular teacher leader (C1), the head of science, after her participation in an action-research project during a sabbatical year.

For teacher C1, one of the main interests for introducing some innovative teaching in her department is the promotion and improvement of teachers' cooperation. C1 considers that state schools generally forget the importance of the social dimension among teachers, in contrast to the approach of large companies and how they organise their workforces. For teacher C1, as head of the department, the introduction of teaching innovations is partially a strategy to encourage teachers' cooperative work and a sense of team. She also considered that to work on teaching and learning strategies in a more systematic way would be very useful for them in order to audit their results and guide their future selection of strategies. She complained that innovations and participation in educational activities are too often proposed not for solving well-identified problems of the school but following other interests.

The innovation teacher C1 is supporting in her science department is related to the teaching and learning of scientific talk. The reason for choosing this topic was that science teachers in School C have long discussed the fact that the examination answers of some students show less knowledge than the knowledge they consider students really have. In this sense, students seem to face great difficulties in expressing their scientific knowledge when asked to explain or justify it, for instance. Analysing this assessment problem, teachers' realised that students found it difficult to express their scientific knowledge in the exam because this competency was not explicitly taught. Due to this, the teachers decided to focus more deeply on the teaching and learning of science talk.

How School C teachers and their teacher leader C1 addressed this issue was strongly influenced by educational research in the field, mainly through the participation of teacher C1 in LIEC (Language & Science Education), a research and innovation group of science teachers, science and language teacher educators and researchers. LIEC is interested in the use of different cognitive abilities, such as describing, explaining, justifying and posing arguments, in the specificity of the science classroom.

The particular innovative proposal science teachers of School C are working on consist of teaching explicitly each of these cognitive abilities (description, explanation, justification and argumentation) in the science classroom. They have chosen to focus on one cognitive ability each year of the secondary schooling, starting with description and ending with argumentation.

All teachers in the science department are involved in this initiative, but, from C1's point-of-view, some of them hold educational rationales that make a coherent implementation of the innovation difficult. In particular, C1 has realised that teachers hold different views in relation to the summative or formative purpose of assessment, which makes it difficult for them to realize and agree at a deeper level with the theoretical framework about learning which is behind the work on scientific language. However, C1 emphasises that it is very positive that working on the innovation has provided a forum where teachers need to make explicit their educational philosophy and beliefs, because once in the "open air" they can be identified and discussed. In this sense, and despite the difficulties, teacher C1 considers that working on some sort of curriculum innovation has helped them in developing a culture of collaboration.

Science innovation in School D: "Integrating the environment in the Science curriculum"

The of School D was originated bottom-up, coming from a decision taken by the whole group of teachers, but partially supported externally with the help of an advisor. As an anecdote, teachers explain the origin of the innovation when a teacher commented that their school would have been the same even if it was located in the middle of the city of Barcelona. She was referring to the fact that, even though they were situated in a privileged area near a National Park, this was not reflected in the curriculum they were teaching. After realizing this absence of context and environment, they decided to implement different actions to integrate the study of the neighbouring woods and river into their curriculum.

To do so, in 2000, School D developed a proposed strategic plan for the next 3 years. They got financial support from the educational authorities for putting into practice this proposal, which included, among others: entering the "Escola Verda" (Green school) environmental schooling state programme; participating in the well-known project "Rius" (Rivers); harvesting an ecological vegetable garden; building a meteorological station, etc.

As part of this strategic programme, School D received the support of an external advisor[13]. Together with this advisor, teachers in School D prepared different nature itineraries for exploring the nearby woods and river. These itineraries had a different focus (vegetation, animal life, landscape, etc.) for every 2-year cycle of schooling (pre-primary, lower, medium and high primary schooling).

From the point-of-view of the advisor of School D, the focus on the environment was a very good "excuse" to work more deeply on the content and pedagogy of science teaching. Whilst School D could have been considered as pedagogically innovative by following innovative curriculum materials for the teaching of science, such as the "Ciències 3-6" and "Ciències 6-12" projects[14], the truth is that they were not feeling confident about their science teaching and their own science knowledge. The project of integrating the school in its environment was very helpful in focusing interest in the teaching of science and highlighting problems and limitations that were faced and overcome with the help of the advisor.

From the point-of-view of the teachers involved, the product of this collaboration was a growing enthusiasm for the school environment and the scientific knowledge necessary to teach it. Teachers found it very exciting to design the itineraries by exploring the area, studying the vegetation and animal life, etc. and spent much of their own free time on this. They also reported that students´ motivation was very high when this fieldwork was proposed to them. When the strategic plan came to an end, teachers wanted to continue with this innovation and successfully asked for the collaboration with the same advisor to continue for an extra year.

The expectation of School D is not to have all this richness in environment and materials only for themselves: they would like their school and itineraries to be open to other primary schools and to establish some networking. In this sense, they are planning to write a proposal for an "Aula de Natura", that is, an open space where students from other schools could meet, be introduced to the itineraries and gather after the field work to complete written tasks. Teachers in School D know this project is very ambitious and will demand a lot of their time and effort, but they are used to participating in one project after another, and this seems to them a necessary step forward.

[13] The advisor of School D was a secondary school science teacher with a long tradition in teacher education.

[14] These curriculum materials, as was previously mentioned in the description of School B, were developed by a group of teacher educators, teacher leaders and researchers to meet the requirements of the early nineties national reform. The approach to the teaching of science used in these materials relies on the idea of “school science activity”, based on observation, experimental work and modelling in science.

Having a strong tradition, as many small rural Primary Schools, of teachers' cooperation, in School D most of the decisions are taken by the whole group of teachers. After contacting them through their advisor, School D teachers met and selected two representatives to become part of the EUDIST project.

The starting point: an analysis of teachers' initial perceptions of best practice in school-based Science innovation

As a starting point of the EUDIST project in Spain, teachers and teacher leaders from each of the selected schools were asked to justify why, from their point-of-view, the innovation they were introducing in the science teaching of their school was a "good practice". They were also asked to discuss/provide some examples of products of their innovation.

Perceptions of good practice in School A

Teacher leaders A1 and A2 answered showed a perception of good practice at two different levels: "good practice" for teachers themselves and "good practice" for students.

Regarding teachers, the process of being involved in an innovation is considered by teachers A1 and A2 to have reinforced the cooperation among teachers and their sense of belonging to a particular school with a particular identity: a pedagogical and didactical profile which they have developed themselves and which is well-known outside the school.

Regarding pupils, teachers A1 and A2 highlighted aspects directly related with the content of the innovation, considering the innovation a good practice mainly because students play the main role in their progress: they can now visualise their initial and final state, participate in their evaluation and in the evaluation of others and anticipate the actions they need to undertake.

As examples of products of their innovation, teachers A1 and A2 selected some of the papers they had produced collaboratively for a teacher journal.

Perceptions of good practice in School B

According to teacher leader B1, the innovation had its main impact in the fact that the learning demand placed on the pupils becomes explicit both for teachers and the students themselves. This systematisation of the curriculum

has meant for the first time in School B to have the same final exam for all students of the same level, irrespective of whosoever taught them.

However, teacher B1 has been responsible for most of the work involved and considers that the traditional dynamics of the department meetings do not help to focus on methodological aspects of teaching, but on the daily logistics of the school.

For teacher B2, her participation in the innovation, particularly during the experience of having B1 as advisor and co-teacher in her classroom, is a very positive experience that has met all her expectations. She highlights as the most important characteristic of this innovation the fact that it allows the teacher to reflect on what is the final aim of teaching, showing him/her strategies to help the student to become an autonomous learner. She also mentions that for students this way of teaching means actually learning how to build up their own knowledge, instead of being presented with "ready-made" finished knowledge, which will be important for their future learning.

As examples of the innovation teacher B1 chose the planning of materials done around a learning objective. Teacher B2 chose as a good example of the innovation some classroom teaching materials that both B1 and she had used during their experience of co-teaching.

Perceptions of good practice in School C

Teacher leader C1 highlights the innovative activity as good practice because she considers it as an opportunity to work on the cohesion of the members of the department, in the sense that criteria, teaching and assessing strategies, educational philosophies etc. need to be more coherent in the group. She considers this journey towards a more coherent and cooperative team of teachers as an on-going process, in the sense that the change of paradigm that would be necessary for some teachers in some aspects is very difficult to make, and requires time for reflection, experimentation and personal construction.

Regarding the particular topic of the innovation chosen, C1 considers it a good example in the sense that by reflecting on the assessment done from the first to the fourth year of compulsory secondary schooling, teachers have to make explicit and discuss their views of it. There is an impact also on their teaching to focus on science talk, for instance, working with students about the differences in describing a phenomenon or explaining a phenomenon.

Teacher C2 focused on students' results to judge the quality of the innovation. In this sense, he mentions that this innovation is a long-term experience so student results wouldn’t be noticeable in the short term. However, he considers that participating in this innovation has made him realize that the majority of the textbooks and teachers' explanations mainly use descriptive language,

whereas the assessment questions are generally focused around "why", demanding explanations, justifications or argumentations without working them explicitly in the science classroom. Recognising the contradiction between what is taught and what is evaluated is, for C2, a most interesting and important starting point.

Teacher leader C1 selected as a product of the innovation some teacher guidelines she has prepared to help her colleagues in the implementation of these new teaching strategies. Teachers C2 selected as products of the innovation some teaching materials and examples of the assessment used.

Perceptions of good practice in School D

Teachers D1 and D2 elaborated a joint questionnaire about the innovation taking place in their school. They also filled another questionnaire with their personal views.

Both teachers D1 and D2 show in their writing satisfaction for having participated in the innovative process in which their school is involved. They consider their success in implementing all the initiatives they included in their strategic plan to be due to the support they received, in particular by the community surrounding the school (parental associations, non-teaching school staff, etc.) and the fact that all the teachers worked together in this initiative. This last point is particularly important because, being a little school with only one group of students per level, the teachers traditionally work too alone, each of them with their group of students. They feel proud and empowered by the work they have done, desiring to continue this work by sharing their achievement with other teachers and schools.

As examples of their innovation, School D presented a CD with all the materials relating to their innovation, from school-planning documents to the actual nature itineraries and students' worksheets.

The Curriculum Workshop in Spain

A central aspect of the EUDIST project is the use of a particular approach, the Curriculum Workshop, for supporting school-based reform. Following Mulder & Thijsen (1990), this approach is defined as a pre-structured discursive meeting where curriculum is justified and developed collaboratively. The CW is a systematic framework for supporting bottom-up curriculum decision-

making. In this sense, it can also be considered as a Continuous Professional Development (CPD) scenario.

The general aspects of the CW approach have been already described in the introduction of this book: gathering teachers and educational stakeholders, deliberation on key-questions, discourse rules, equality of participation, goal-orientation towards a curriculum document, etc. The Spanish CW follow this structure but adapt it to its goal: the support of innovative teachers' collaborative reflections to enable the construction of their voice concerning school-based innovation in the Spanish school. Both the constructed teachers' voice and the process of constructing it are of interest in the Spanish EUDIST project, giving to the Spanish CW both a knowledge-creating and professional development dimension.

The knowledge-creation dimension of the Spanish Curriculum Workshop. Deliberation among "innovative" teachers

Change towards bottom-up educational reform demands from schools and teachers that they originate, design, participate actively, reflect on and be critical of school reform. This is not an easy task for teacher leaders and teachers, who respectively need professional knowledge and skills about how to support this process and fully participate in it. Knowledge about school-based innovation is also necessary for educational policy-making and teacher professional development which aim to support this bottom-up approach.

As school-based reform is a recent trend in education, the existing examples of teachers and schools managing to put it into practice may be regarded as good sources for such knowledge[17]. Despite their idiosyncrasies, these examples hold a great deal of experience about the challenges of facing innovation. There is knowledge embedded in the practice of the teachers struggling to put school-based innovation into practice.

External study of initiatives of school-based innovation could be a way of obtaining the sought after knowledge. However, this top-down approach is not the standpoint of EUDIST. In the same way that Hargreaves (1999) claims that teachers have to be at the heart of the creation of didactical and pedagogical knowledge for their teaching, we consider that innovative teachers involved in school-based reform have to be at the heart of the creation of the knowledge about the process of designing, supporting, running, auditing, etc. school-based innovations. This knowledge is more than pedagogy or didactics: it is the teachers' professional knowledge which is useful in a school-based reform context. The reason for putting teachers at the centre of this knowledge-creation exercise is the necessity of a closer relation between generation of educational knowledge and actual educational practice (Fullan & Hargreaves 1992; Cochran-Smith & Lytle 1999).

How can this knowledge be obtained? We consider the CW a possible scenario for this knowledge to emerge in the form of the innovative teachers' voice. We speak about *constructing* this voice because we consider it the result of a process. It is the voice that innovative teachers construct together in a guided process of collaborative reflection and deliberation around particular key questions concerning their school-based innovation activity. The results of their deliberations are used to produce an outcome in the form of a final document for future educational decision-making. In this sense, the Spanish CW can be understood as a process for supporting the construction of this *knowledgeable* voice of the teachers involved in school-based reform.

This voice is knowledgeable and interesting not only for those external to the teachers (policy makers, teacher educators, researchers) but also for the teachers themselves. First, because from a school-based reform approach teachers have power and autonomy to make educational decisions, and need to be informed in this sense. Second, because we consider that the collaborative generation of the innovative teachers' voice can foster understanding and improvement of their singular practice, helping innovative teachers to come to know the epistemological basis of what they do in school-based reform.

The professional development dimension of the Spanish Curriculum Workshop: collaboration, reflection & empowerment

To face school-based reform is a very challenging experience for teachers. Every aspect of teachers' professionalism[18] becomes challenged: collegiality, all types of knowledge[19], values and beliefs, leadership, autonomy, etc. School-based curriculum reform implies radical changes in the character of the teaching profession, from being basically a profession centred in the classroom to one focused on the teachers' curriculum design work outside the classroom and among colleagues (Calgren 1999). To face the challenge of this new professionalism where relationships with colleagues, negotiation and responsibility play a crucial role (Hargreaves 1994a), teachers need new types of professional development and support that explicitly address these issues.

[18] We agree with Lang, Olson, Hansen & Bünder (1999) that *"different reform agendas embody images of different professional ideals"* (p.9) In this sense, the school-based reform agenda implies a different view of teacher professionalism: that of a professional who controls the curriculum (McCullough et al. 2000) within a school context. This emphasises the role of the relationship with colleagues and the community, negotiation and responsibility in teachers' professionalism (the "new professionalism" of Hargreaves 1994)

[19] There is an extensive amount of research characterising teachers' knowledge. We refer here to three well-known (in the literature) dimensions of teachers' knowledge: content knowledge, pedagogical content knowledge (following Shulman) and practical or craft knowledge (following Van Driel).

There are four metaphors of the teacher in school-based reform that suggest directions for this new professional development. In school-based reform, the teacher has to be understood and supported as a knowledgeable agent, as a social agent (in a community), as a metacognitive agent and as an impelling-reform agent. These metaphors are deeply embedded in the design of the CW approach of the Spanish EUDIST project, thus emphasising the CPD dimension given to the CW procedure.

The teacher as a knowledgeable agent

This metaphor has already been discussed in the previous section about the CW as a knowledge-creating scenario in the school-based reform context. The starting point is the already mentioned consideration of innovative teachers, those who have long experience of introducing innovation at the school level, as knowledgeable about this process. The support to be given by CPD initiatives, then, is helping teachers to make explicit this knowledge and produce useful outcomes from it. This could be done in different scenarios, but our proposal is to support a process of collaborative reflection so that new versions of teachers' knowledge can be constructed and became helpful at both individual and also at school level.

It becomes necessary to stress here that understanding teachers as knowledgeable agents does not necessarily mean that all the knowledge to be used in school-based reform comes from teachers. In this sense, the CW general procedure gives a secondary but active role to educational experts, and literature and other forms of educational knowledge should be also available in the form of information booklets if considered necessary. In the Spanish version of the CW, however, we were intending to capture what the innovative teachers' know without any other external influence, as a starting point for characterising school-based innovation in Spain. In this sense, the role of the external experts was minimal and the information booklet contained only the information that teachers' considered necessary for the deliberations to take place.

The teacher as a social agent: the need to promote teachers' collegiality and collaboration.

School-based reform implies teachers' working together in the innovation design, support, and when putting innovations into practice, etc. This implies deliberation and negotiation among colleagues for shared decision-making. A culture of collegiality and collaboration play a crucial role in this situation. All recent initiatives dealing with educational change from a bottom-up approach (School-based Collaboratives, Communities of Practice, Learning

Communities, Professional communities, etc.) stress the value of collaboration and collegiality in helping the development of a shared vision of school-reform and teachers' practice in these challenging settings.

Collaboration and collegiality is also a source for teacher learning and teacher change[20]. Following Briscoe and Peters (1998): "Collaboration facilitates change because it provides opportunities for teachers to learn both content and pedagogical knowledge from one another, encourages teachers to be risk takers in implementing new ideas, and supports and sustains the processes of individual change in science teaching" (p.51). Fullan (1993) also considers the ability to collaborate as one of the core requisites of post modern society, basically due to the fact that there is a "ceiling effect" on how much we can learn from our personal reflections without interaction with others. All these ideas resonate with socio-cultural views of learning, thus emphasizing the role of teachers' working with peers in teachers' professional development scenarios.

In the Spanish CW, the collaboration and collegiality among innovative teachers have been supported by using different CPD strategies (sharing narratives for getting to know each other; working in small groups as safe scenarios; requiring everyone's agreement for each statement, etc.) that will be introduced in more detail in the following sections.

The teacher as a metacognitive agent: the need to encourage teachers' reflection.

Despite the extensive amount of research discussing teachers' reflection (at what moment, with what purpose, about what, with whom, etc), the consideration that reflection is essential for teachers' professional development is not problematic. In the context of the Spanish CW, we have focused on ideas of reflection *about* practice, in our case, reflection about the practice of being an innovative teacher.

Reflection *about* the practice of being a school-based agent of reform aims to help teachers to re-think their experiences in this new professional arena and learn from them. It is a critique of practice that involves, following Day, reflection about "the values which are implicit in that practice, the personal, social, institutional and broad policy contexts in which practice takes place, and the implications of these for improvement of that practice" (1999, p. 222). In this sense, the CW in Spain aimed for teachers' deliberations about their practice to cover all these contexts: self, school and broader educational ones, which are all embodied in the process of school-based reform.

[20] We consider here the concepts of teacher learning and teacher change as deeply interrelated, and also crucially bounded with the idea of reform. Following Ball and Cohen (1999), the implementation of reforms can be seen as essentially a matter of teacher learning.

The critical reflection about practice that it is promoted in the Spanish CW could be done either at individual or social level. However, as it has been explained in the previous section about teacher collaboration, collaborative reflection brings teachers' learning further along and therefore, is a better strategy for teachers' professional development approaches.

The teacher as an impelling-reform agent: the need to reinforce teachers' empowerment.

To Bybee, empowered teachers are those who are prepared to create or adapt science education materials to "enhance the teaching and learning of science" (Bybee, 1993, p.159). In school-based innovation scenarios, this idea of empowerment needs to be adapted to include the school dimension and the idea of the teacher as an impelling-reform agent. Then, empowered teachers in school-based reform are those who are prepared to create or adapt curriculum innovations in their schools, enhancing along the process the quality of their school as institution, their own professional development and the learning of their students.

According to Bybee, empowerment has five qualities: significance (transcendent vision aiming to improve science education); knowledge, skills and attitudes (a sense of competence and mastery); community (achieved through teachers' collaborative and collegial work in their common task of improving science education); enjoyment (from understanding, engaging in meaningful work and developing personally and professionally) and responsibility (assuming the responsibility of improving science education in their classrooms) (p.159). Due to the particular purposeful sample of teachers selected, many of these characteristics should be found, theoretically, in our innovative teachers. They are expected to hold a sense of transcendence regarding school-based innovation, which is the reason why they participate in it. In general they feel competent enough to originate or participate in innovation, as they are actually doing. They are expected to have a desire to innovate at school level with their colleagues, being involved in school-based innovation. They also are expected to feel enjoyment and be responsible towards the initiative they are participating in. In this sense, we can say that the teachers' participating in school-based reform should be already empowered professionals. However, the collaborative reflections that take place in the Spanish CW regarding the major difficulties these teachers' experience in school-based reform can show possible sources of lack of empowerment in any of these dimensions. The CW approach, by identifying possible problems and discussing the necessary support to overcome them, can reinforce the empowerment of the participating teachers.

Participants in the Spanish CW: ensuring diversity of views.

As it has been widely described in section 3 of this chapter, the four Schools selected as SBC's in the Spanish EUDIST project are examples of well-known Spanish schools where a range of school-based science innovation is taking place. For participation in our CW, we invited two teachers from each of the schools, including teacher leaders for each innovation, if any. All the 8 teachers were experienced teachers, 5 of them female. 6 teachers came from secondary school and 2 from primary.

Apart from the teachers and teacher leaders themselves, other participants took part in the Spanish CW. One of the researchers of the EUDIST Spanish team played the role of facilitator, basically moderating the deliberation process, introducing the different methodologies and tasks to be discussed and carried out, and guiding the process towards the achievement of a CW outcome: the curriculum document.[21].

Preparation of the Curriculum Workshop: sharing teachers' experiences through teachers' narratives.

The purposefully chosen diversity in school and innovation profiles of the selected SBC's made it necessary to establish a common ground for a fruitful deliberation before the CW. First, it was necessary that all participants could know each others' school and innovation profiles. Second, it was important that participants started to reflect on their own experience in the innovation process. To accomplish both aims, teachers were asked to elaborate a piece of writing which, in addition to be a reflective exercise, would be circulated among the other teachers for introducing each other.

The piece of writing teachers were asked for was a personal narrative of their own participation in the innovation. To help teachers in this writing exercise, a writing-frame was provided, including the following sections:

[21] Two other members of EUDIST, the national Spanish coordinator and one of the EUDIST central coordinators, act as external observers. Due to language problems (Spanish CW's were carried out in Catalan, the first language of the teachers present), this observation from the EUDIST external expert was undertaken in an indirect way, with the national researcher explaining and translating when necessary. The particular objective of the Spanish CW, which was to become a forum where innovative teachers could reflect openly and collaboratively about their experiences in school-based reform, made it unnecessary that other educational stakeholders or agents not directly involved in this process were present.

Contextualization (introducing the teacher, the school and the innovation); Story of the innovation (starting point or origin, topic, methodology followed, state of the innovation, future perspectives, etc.); description of the teachers' own role in the implementation of the innovation and reflection about why they consider the innovation to be good practice and in which respects. Teachers were also asked to gather examples of materials than in their view would constitute good examples of the implementation of the innovation rationale, as put into practice[22].

The methodology of the curriculum workshop: promoting teachers' collaborative reflections.

To promote teachers' collaborative reflections, different methodological strategies were planned to be used alongside the Spanish CW meetings. Theoretically, these strategies are grounded in the ideas of teacher reflection, collaboration and empowerment already introduced in this chapter. In the following table (Table 4), the methodological strategies implemented in the Spanish CW are briefly described.

Strategy	Description
Focus-orientation	Deliberation focused on a particular aspect of school-based science innovation at a time.
Step-by-step reflection	Every aspect of school-based innovation would be first brainstormed and later discussed in more detail. The idea is to help teachers´ reflection by starting with concrete experience or context-dependant ideas and moving to more abstract and general ideas.
Small-group deliberation	Brainstorming is done in small-group deliberation to initiate the discussion of ideas first in a "safer", atmosphere. Small-groups gather 4 teachers coming from each of the SBC's. Not knowing each other nor each other's schools, a deeper explanation and justification is promoted.
Whole-group deliberation	Whole-group deliberation would consist of each small-group of teachers presenting their ideas and the whole group trying to combine them to develop a global view on the particular aspect discussed. To accomplish this, teachers would consider two alternatives, one from each small-group, which they would need to discuss in order to agree final outcomes of the discussed aspects.
Writing cards	Selection, organization, documentation and comparison of the ideas coming out from the small-group deliberations were done using writing-cards for each agreed statement. These cards help teachers to agree on concrete statements instead of

[22] A summary of part of these narrative writings has already been introduced in the section on teachers' perceptions of innovation.

	freely brainstorming. They are also a physical report of the small-group discussions which will be used for comparison with the other group work and elaboration of the final documents.
Flip-chart maps	The whole group view of each of the topics discussed was recorded using flip-charts where written cards were organised into a final schema or concept map around the aspect discussed.
Deeper reflection	In a second step, whole-group maps coming from brainstorming would be deeply reflected upon by classifying the ideas in broader abstract categories and stating positive aspects, negative aspects and open questions still remaining for each of them (See Fig.2).
Goal-orientation	Teachers' work was goal-oriented towards the production of a final outcome: a document that reports the results of their cooperative deliberations and reflections.
Distance reflection	The final documents of the CW' s were circulated among the teachers to obtain their personal comments on them, allowing further personal reflection from a distance.

Table 4: Summary of the methodological strategies used in the Spanish CW.

The structure of the Curriculum Workshop: a sequence of three meetings

The CW was planned as a sequence of three different sessions within a two-week timeframe. This structure was designed so that teachers had some time to know each other, develop some group coherence and were able to reflect during and between the meetings. Each of these sessions, referred here to as

CW1, CW2 and CW3, was planned with specific aims, around a particular Key Question on school-based innovation to be discussed and a Curriculum Document to be elaborated during the session (See Table 5)

	Description of CW planning
CW1	Introduction: the teachers would introduce themselves, their schools and the innovations they were implementing. To do so, they would use their **narrative writings**. First small-group brainstorming: Teachers would be asked to start their brainstorming about two crucial aspects of the implementation of innovations: first their **motivation to be involved in science innovations** and later, **changes identified during this experience**. Following the planned methodology, teachers would be asked to write the ideas they agreed upon on writing-cards. First whole-group brainstorm: Using a flip-chart, the cards of both small groups about the topics of motivation and change would be compiled and used by the whole group of teachers to **construct a pair of schema of their agreements** on what motivates and what changes during school-based innovation
CW2	Small-group deeper deliberation: Teachers were expected to elaborate more on their ideas about motivations and changes related to being involved in the implementation of innovations. Teachers would be asked to categorise their ideas from the previous CW in broader categories. They would be asked to discuss in small groups both **facilitating and constraining aspects, in addition to open questions about the identified motivations and changes.** Whole-group deeper deliberation: In subsequent whole-group work, teachers would be asked to develop/construct a final table for each topic (motivation and change) stating their final agreements.
CW3	Small-group construction of recommendations: CW3, as the final step in the Spanish CW, would be devoted to achieving a **final set of teachers ´proposals/requests to all educational agents for supporting and improving success in the implementation of innovations at school level**. To accomplish this, teachers were to make use of their previous reflections and final documents from CW1 and CW2 to inform them. Whole-group construction of recommendations: Teachers would work together in the construction of a set of recommendations / proposals that would facilitate the positive changes identified; that would diminish the difficulties pointed out and that would highlight the open questions remaining regarding the implementation of innovations at school level

Table 5: Description of the different planned steps structuring the Spanish CW.

The enacted Curriculum Workshop: a brief description of events

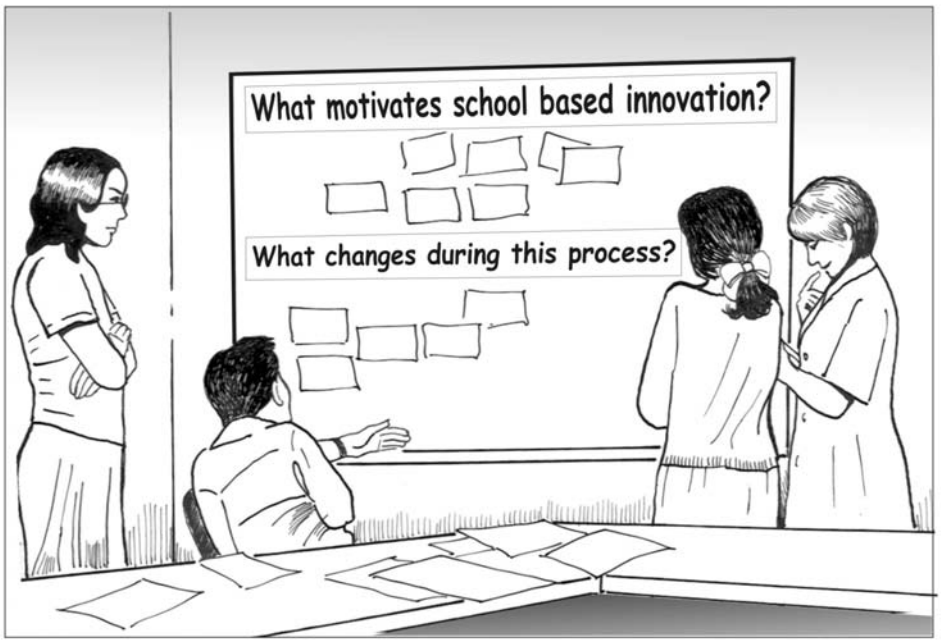
CW1 started with teachers' presentation of themselves, their school context and their particular "story" in relation to school-based science innovation. They had previously produced and circulated their narratives, which were intended to be used in this presentation. However, teachers' did not follow these writings but

modified their presentation to focus on links with each other experience, highlighting the noticed differences or similarities among the different "innovation stories". The atmosphere was relaxed, with teachers asking each other questions during their presentations to clarify aspects and openly showing their surprise and interest in different aspects mentioned. The questioning continued during the coffee-break time.

The second part of the session was organised around two brainstorms that were intended to answer the CW1 key questions:

What motivates school based innovation?

What changes during this process?.



This was intended to find the *"innovative teachers'"* perceptions about two main dimensions in the process of implementing school-based reform: the dimensions of *motivation* and *change*. Teachers worked first in small-groups of 4 teachers to discuss factors for each of these dimensions. Each factor was written on a card. With these cards, the whole-team of teachers produced a scheme of their ideas about *motivation* and *change* on a flip-chart. Multidimensional views of both dimensions emerged. After the meeting, a digitalised version of both schemes was circulated for additional comments or modifications.CW2 intended to produce a deeper reflection around the factors discussed in CW1. Teachers were asked to organise in broad categories the ideas from their previous brainstorm. In particular, they were asked to focus on the important category of *change* and to reflect on *what facilitates and what makes more difficult the "positive changes" identified in the school-based innovation process.* Teachers also were asked to identify *open questions* or questions they did not already have an answer for, regarding these aspects. As usual, this was done first in small-group work and later in a whole-group discussion.

The abstractness of the CW2 task was clearly more challenging for the participating teachers and some of them left a little bit before the whole-group discussion finished. In this sense, the final document was mainly the result of the deliberations of teachers B1, C1, B2 and A1[23], most of them teacher leaders of their innovations.

As a final Curriculum Document, teachers elaborated a table for the dimension of *change* along the process of school based reform with two entries: the categories of change identified versus what facilitates, what makes it more difficult and what remains unresolved for each of them . This document was also circulated among the teachers as a preparation for the final deliberation meeting of CW3.

In CW3 teachers were invited to participate in a discourse to elaborate their *final proposals and recommendations addressed to educational stakeholders about how to support school-based innovation in order to increase success*. The same methodology (small-group/plenary group discussion) was used. Teachers developed and agreed a set of recommendations/proposals that would facilitate the positive changes identified; that would diminish the difficulties pointed out and that would highlight the open questions still remaining, regarding the implementation of school based innovations. In this sense, CW3 was focused on discussing; agreeing and documenting the characteristics of what are, essentially, successful practices of school-based innovation, and what can be done to support them in practice. This final schema/map of ideas was considered by the group of teachers as the final Curriculum Document of the

[23] Teacher A1 could not attend all this meeting for personal reasons but she participated actively online, circulating her comments on the final document before CW3.

Spanish CW, being the product of the complete deliberation and step-by-step reflection process followed along CW1, CW2 and CW3.

After CW3, the list of recommendations/proposals of the Curriculum Document was digitalised and circulated among teachers for internal validity, together with a feedback questionnaire[24] about the CW procedures, aims and results. These were used some months after the meetings. Findings from this feedback questionnaire will be reported in the following sections.

Outcomes and findings from the Spanish CW: innovative teachers' voice and professional development

To analyse the outcomes of the CW procedure, all observations of video-recorded CW discussions, final documents produced by the teachers in each of the sessions and readings of the notes taken in the observation diary of the facilitator were used.

Teachers' perceptions of school-based scientific innovations: An analysis of the CW outcomes to construct the innovative teachers' voice.

During the three CW conducted in Spain, the participating innovative teachers constructed reflectively and collaboratively their perceptions about the process of school-based innovation around the dimensions of motivation, change and support. In the following, we report teachers' deliberations on these topics[26].

What motivates school innovations to take place?

Teachers' perception about what motivates school-based reform is organised around two dimensions: motivations at the personal or the teacher level and motivations at the school level.

[24] Feedback from the participating teachers after the CW experience was sought using an open feedback questionnarie. In this questionnaire, different aspects of two categories were focused upon: evaluation of the CW as a deliberation process to promote teachers' collaborative reflections (methodology, impact, CPD dimension, etc) and the evaluation of their own outcome document of recommendations for school-based innovation (implications, priorities, steps to be followed, etc.)

[26] To be able to report teachers' deliberations during the meetings, we use the teachers' discourse throughout the CWs and the final curriculum documents, in the forms of schema and charts, as elaborated by teachers.

Teachers agreed that a personal motivating factor for being involved in school-based curricular innovation is a feeling of self-dissatisfaction with the actual curriculum. This dissatisfaction is related with a lack of enjoyment and sense of routine in the science classroom, either for teachers or students:

> *B1: This dissatisfaction comes from the fact we do not enjoy ourselves in the classroom. You have posed 14 problems, you have solved them, you do this and that… so what? … Instead of that you could be saying we have discussed today [in the classroom], we have engaged in deep discussion, we have shown evidence, we have done another experiment, … this has another lure, hasn't it?*

In this sense, the innovation is seen as a solution to routine in the form of an enjoyable challenging experience, *"a way of not repeating yourself, of setting new challenges to yourself"* (teacher B1).

This idea of the innovative teacher as someone who sees challenge in a positive way could be traced along all teachers' discourse. Other personal characteristics, such as being someone who is able to learn from others (your colleagues, external experts, the literature), who admits alternative practices to his or her own practices and who is able to share frustrations with colleagues were also mentioned by teachers as necessary to be motivated to participate in school-based innovation. In this sense, a "profile" of the innovative teacher can be inferred from teachers' discourse. The ideas mentioned by the innovative teacher seem to be in agreement with the literature relating to teaching as a life-long learning profession. How to promote such a professional, however, was not discussed.

According to teachers, motivation for school-based innovation also occurs at school level under certain circumstances. They referred to the possibility of teachers' appropriation of an externally imposed reform as an opportunity for change. This was the case of School A, where science teachers took advantage of the experience of piloting national reform to develop their own innovative framework and continue it by themselves. They also refer to the identification of a school problem or necessity all teachers agree on, such as in school D, the necessity to develop an identity for their school according to its environment, as a motivating factor. Teachers give importance to this idea of "School identity" and associate it with school-based innovation, either as a conscious goal or unconscious result:

> *D1: For us, the origin was a necessity to have some identity for our school.*
>
> *A1: We have arrived there now ((pointing at D1))… at the end of the path. I mean, you have started from thinking what sort of school you want to have… We haven't, we have started this path [of participating in*

innovation], we have kept on walking, and at the end, we realize this is the school that we have come up with!

Regarding the conditions that help or motivate innovation to take place, the most mentioned one is related to teachers' collegiality and collaboration. The relationship of teachers with their colleagues is perceived by teachers as the most influential factor regarding school-based reform. Teachers mentioned aspects such as trustfulness in your colleagues' ability and disposition to change; involvement of your colleagues; experiencing a welcoming social environment and being able to discuss and share experiences with them as crucial factors. These ideas were also the ones more difficult for teachers to report, being in some occasions reworded many times before finding a final agreed statement. Teachers seem to face great difficulty in mentioning their colleagues' resistance to change.

Another important practical condition mentioned by teachers is the issue of time. Teachers consider time as a very influential factor in facilitating the participating in innovations. A lot of time is needed for training, preparation of materials, discussion, etc. Teachers also refer to time in a different way, related with understanding the time-scale of educational change. For teachers innovation needs to be designed with a long-term view, but planning for long-term goals instead of for the next lesson is not common in their practice, and becomes a challenge:

C1: We do not use our time for long-term planning. Everyday ok, we meet and we can distribute tasks and share materials and some ideas, and then, we have it! All the year's course is planned!... And what about in two years time? And in three years time?

External support and advice together with promotion of teachers' effective leadership (power in a hierarchy) were also mentioned by some teachers as influential factors. However, there was not strong agreement around the idea of the need for a stronger hierarchy. The innovative teachers faced here a dilemma which has long ago been identified in the literature in contexts very different to the Spanish one: how to promote leadership without simply organising power over others (Little, 1989).

For teachers, the motivation to innovate develops together with the innovation, related with the continuous feedback received from many agents. For instance, teachers mentioned that positive results of the innovation process, either in terms of students' performance or in terms of teachers´ improvement (self-training), contribute to the feeling of satisfaction that was looked for when deciding to participate in the innovation. In this sense, teachers consider that the participation in innovative projects motivates in itself for further participation in innovative projects. This shows that innovative teachers show a very positive view of innovation, conceiving it as a "good experience" that will promote further desire to change.

What changes are perceived from participating in school innovations?

Teachers grouped their perceptions about change to include various factors, with strong emphasis in the changes in the relationship with colleagues, changes for the school and for the students, emphasising the latter.

Changes identified in relation with collegiality referred particularly to positive changes in the relationship with colleagues from the same department, mentioning ideas such as: creating reflection / development groups, increasing friendship, feeling the involvement of partners, sharing experiences among partners and learning from each other. Teachers also mentioned the fact that, once the innovation was established [? – your phrase doesn't work – or "in place"] and showing positive results, it could awaken the interest of teachers from other departments and spread the innovative fashion elsewhere within the school (as happened in School A). Together with these positive changes, however, teachers referred also to the fact that not all their colleagues usually show the same enthusiasm and some of them, despite being interested, seem not to be sufficiently convinced to participate.

In relation with the school as an institution, the issue that teachers mentioned more often was the fact that innovation could be helpful for creating a coherent and unified school identity. Teachers' statements were about ideas of unifying discourse; making explicit and sharing educational priorities and philosophy and unifying criteria. All these statements convey the idea of a positive change at school level in relation with school-based innovation: to become a school where educational philosophy and discourse becomes more explicit, agreed and shared by all the staff, providing the school with a particular identity.

Teachers also mentioned that participating in reform broadens the school curriculum and helps in the systematisation of the work that is done. In this sense, the school becomes a more professional and creative institution. Teachers' discourse around these topics resonates with literature ideas of schools as learning communities and school-based enquiry.

Regarding the students, teachers basically mentioned how the innovations they were implementing implied a different role for their students and a different classroom (a generally noisier one!). This was mainly the case of teachers who were implementing curriculum innovations that imply a strong pedagogical change, such as teachers from schools A, B and C. They mentioned the increase in students' responsibility, autonomy and involvement in the learning process (for innovations A and C dealt with self-regulation of students' learning) and an increase in the comprehension level (school B dealt with science modelling). The changes identified at the student level were always mentioned in relation to the particularities (particular pedagogical approach) of the innovation. In this

sense, other benefits of school-based innovation at teacher or school level seem not to have a direct effect on students, from the teachers' viewpoint.

Teachers´ also identified some changes at a personal level, either related with their feelings during the innovation process (overcoming initial fears, increasing self-esteem and satisfaction) or developmental (learning from one's mistakes, learning concrete pedagogical or didactical content). This category of personal change was the last one to appear in the teachers' discourse, and needed an input from the facilitator to emerge. Teachers did not show difficulties in expressing views about how they have changed as persons and professionals during the process, but seem not to see this development as an important outcome of the innovation, focusing instead more on the students and the school.

What are the recommendations from teachers about how to support school innovation?

Teachers deliberated about three sorts of proposals aimed at the different educational stakeholders and with different focuses. These proposals regard:

- Continuous Professional Development and Teacher Education
- School dynamics
- The political and social context

Continuous Professional Development and Teacher Education

Regarding initial teacher education, teachers would like more serious training in general pedagogy (such as group dynamics) and psychology of learning, instead of a focus only in disciplinary content and Pedagogical Content Knowledge. They also consider that initial teacher training has to combine both theory and educational practice in a much more satisfactory way than nowadays, where student teachers are for a very little time in the school (generally a trimester). Due to the fact that many of the participating teachers are also student-teacher mentors (5 of them), this comment comes from those well aware of the initial training regime. Also in relation to this, they suggested that the most experienced teachers should devote part of their time in accompanying novice teachers and helping in their initial training[27].

[27] In the Spanish educational system there is not a training period for newly qualified teachers. Once accredited with a teacher qualification, one starts teaching in an equal position as any other more experienced teacher.

About Continuous Professional Development, teachers demanded more training about trans-disciplinary aspects that could involve the whole school staff, such as emotional education, solution of conflicts or innovative assessment. For teachers, success of the innovation in terms of students' improvement would increase if all teachers in the school worked on the same innovative ideas from their different subjects. In this sense, these teachers recognise the importance of seeking to give a "whole school" dimension to their innovations, even thought this is not always possible in practice.

Regarding how these CPD activities should be organised, our innovative teachers claim that teacher educators should have both theoretical knowledge and experience of the implementation of theoretical ideas in schools. Teachers do not want to be trained just at the theoretical level, but they emphasize the role of theory in this process, in particular theory that has informed activities already successfully implemented in the school by the teacher educators. More evidence-based content would be desirable in CPD initiatives. In this sense, the innovative teachers are in agreement with an idea present in most of the literature about reform and school effectiveness, this is, that "educational reform begins with a clear conception of what works in classrooms" (Harris & Hopkins 1999, p.264)

Related with this idea is teachers' suggestion of the combination of teaching with school-based research as a CPD strategy. They suggest that for this initiative to be really useful, the research to be conducted should have impact at the school level, combining the development of the teacher with addressing school problems. For them, it is too often the case that despite the increasing of teacher professionalism in various forms, the CPD received does not have an efficient impact at the school level.

Teachers also recommend that all teacher education takes into account the school and teaching staff needs and is done during their school time and not at the expense of their free-time, as it is usually the case. For teachers this is particularly important not for themselves (they would do it anyway!) but for including those teachers more reluctant about innovation.

School dynamics

School dynamics was a very interesting category because from our viewpoint, it was the one where teachers had more possibilities for action. However, this seems not to be how the teachers interpreted it. Most of the issues raised were issues that could not be controlled by teachers themselves or, even when they could change them, they didn't refer to them from this perspective. In this

sense, the innovative teachers showed a general lack of empowerment regarding school-dynamics.

Teachers mentioned practical aspects related with the school organisation as very relevant ones. They mention the necessity of more autonomy for schools in decisions related with teaching staff recruitment, demanding that these would be done according to the school's necessities and teachers' pedagogical profiles, instead of by the state and according to teachers' specialisation in subject matter. Stability of the teachers' groups was mentioned as crucial for reform to survive. For them, it was a pity that any non-permanent teacher that "fit" with the innovation profile of their school could be changed by another by educational authority without taking into account their opinions. In this sense, innovative teachers asked for schools to be involved in managerial decision-making. Whether these teachers would like to be involved themselves in this decisions was not clear.

Teachers referred also to the micro politics of the school. They would like important staff members such as principals, heads of department, etc, to be elected according to their innovative professional profile and not for bureaucratic reasons. However, either with or without stronger power positions in the school, they still leave explicitly open the question of how to generate a "good working atmosphere" among their colleagues so that they can collaborate. Again, collegiality is crucial and how to promote it an open question.

Policy and Social aspects

The political and social context for education contained as much inputs as the other more expectable categories, which in our view shows that innovative teachers have a broader view of the educational contexts than just the reality of their school.

For the innovative teachers, the educational administration should consider innovation as an essential part of education and the teaching profession. In this sense, innovation should be understood by educational authorities as the necessary reaction to an educational problem. Diagnosing problems in a school should be accompanied by immediate action plans based on didactical/pedagogical orientations for solving them. However, giving a role to change is not contradictory to asking for certain stability in the educational systems. Innovative teachers are conscious that innovations require time to be implemented and instability causes many innovative efforts to be wasted.

One important aspect that teachers mentioned regarding educational policy is the necessity of certain regulation of the teachers', some "measure" of the

pedagogical competence of teachers that would help them to self-regulate their professional career, "as we expect students to do" teacher A2. They also consider that promotion should be available for teachers depending on their competence, and even some mandatory continuous pedagogical training for professionals who do not meet the requirements ("renewing", in teachers' terms). The innovative teachers, then, regard it as necessary to have a certain culture of accountability, which nowadays is non–existent in the Spanish educational system. Taking into account the controversial view on accountability that emerges from contexts where this policy has a strong impact; it is interesting that Spanish innovative teachers welcome it.

The previous idea is related with the fact that innovative teachers consider that innovation does not receive enough recognition. Teachers would like that innovation becomes a distinctive aspect of teachers' best practice, i.e. teachers' professionalism. In this sense, teachers would like to be compensated and promoted according to their involvement in reform. Better than economical compensations, teachers would prefer the possibility to change their professional profile, for instance receiving more "non-teaching time" to facilitate they enrolment in leading curriculum reform or school-based enquiry. This situation would require more school autonomy regarding the management of the teaching staff, so that the non-teaching time of teachers could be distributed at school level according to school necessities and teachers' competence and leadership. For teachers, some timetable flexibility is necessary for innovation, in particular at the starting points. In summary, teachers would like to receive more external stimulus and resources, both at the school and the teacher level, to innovate.

The innovative teachers also suggest a closer connection between society and school. Teachers consider important to establish an educational contract with society, so that the school is not educating in isolation. Teachers relate this idea of a closer connection with society with the need for a fundamental revision of what should be taught in the general compulsory education. For the innovative teachers it is clear that a new curriculum (in particular regarding science) is needed to include the social dimension in the school.

The innovative teachers' voice about school-based innovation: a summary of results.

The voice of teachers' leading school-based innovation shows the particular view these teachers hold regarding the school-based reform process. We have

summarised their voice around three main ideas that characterise their view of educational change:

- the school dimension of change
- the desire to change
- change in a culture of enquiry

Innovative teachers' voice regarding the school dimension of change.

Teachers struggling with school-based curriculum innovation are teachers who aim at a bottom-up approach for educational reform, but especially at the *school dimension* of this change. In the teachers' voice this latter goal is identified in their desire for achieving "school identity".

For innovative teachers, school identity is what is achieved after long-term successful school-based innovation: a school where teachers have agreed on educational priorities; have developed common criteria; share a basic educational philosophy and have unified their didactical/pedagogical discourse. These trends give the school a particular profile, an "identity" that can be externally recognised, and even well-known if there are good results. In this ideal school, teachers work together and despite individual differences, global teaching is coherent. In this sense, for teachers school-based innovation should focus on curriculum changes that could involve teachers from different disciplines in the same project (e.g. assessment, subject integration, language, environment, etc). According to teachers, to engage the whole school staff in a common project increases the impact of the innovation in the students' results.

The major difficulty in order to achieve school identity is related with the difficulty to engage colleagues in reform. This links with the following idea in the innovative teachers' voice: the desire to change.

Innovative teachers voice regarding the desire to change

Teachers leading and actively participating in school-based reform are dissatisfied teachers. However, their dissatisfaction, instead of disempowering them, is a source of motivation for change. This is because innovative teachers are professionals with a clear life-long learning and problem-solving view of their profession. They are teachers who desire to change (Hargreaves, 1994b),

even if change is hard (Davis, 2003). This view of teacher professionalism becomes an identity factor that differentiates innovative teachers from others. Whether this view of professionalism can be widespread throughout the teaching community or not, and how it could be done, are contradictory ideas in the innovative teachers' discourse.

On the one hand, innovative teachers' consider that the desire to change is related with teachers' character, part of their personality. This consideration is problematic in that it leaves little room for action to support a new professional culture in schools. A consequence of this view could be teachers' request for having greater autonomy at school level for selecting and recruiting teachers according to their innovative profiles. The underlying idea seems to be that if your colleagues are such that they do not want to change, the only possibility for school-based innovation would be to change colleagues. However, on the other hand, teachers also consider that the present scenario does not encourage school-based reform, and relate reluctance to change by colleagues with the current professional culture. Lack of professional incentives (promotion, recognition of leadership), lack of supporting opportunities (such a co-teaching, expert support to novice teachers) and lack of time and a proper time-scale for change, among others, are mentioned by innovative teachers as causing a difficult situation for colleagues to engage in reform.

Here the innovative teachers' voice founds a contested territory among encouraging reform and "pressuring" for it in the delicate scenario of the staff room. On the one hand, recognition and incentives for school-based reform (promotion), which aim at encouraging teachers, give a new role to hierarchy and accountability, increasing pressure on teachers. On the other hand, the present context of the Spanish school does not pressure for reform, but neither encourages it. Involvement from colleagues seems difficult in both scenarios. Despite some teachers advocate for a slightly move towards a more hierarchical and accountable structure that recognises their efforts, the impact this would have on teachers' collegiality remains an open question.

Innovative teachers' voice and the culture of enquiry

The innovative teachers' voice contains lots of references to a culture of enquiry for successful school-based reform. Enquiry seems to be associated with reliable decision-making and increasing professionalism at school level. Among other references to this enquiry culture, the innovative teachers highlight the importance of professional development to be evidence-based; of diagnosing school problems before initiating reform; of using school-based enquiry to address school problems; of systematising teachers' practice for comparability of results; of measuring improvement with empirical evidence,

etc. These innovative teachers' ideas resonate with well-known ideas in the literature such as teaching as an evidence-based practice (Ratcliffe et al. 2005); practitioner research as a source for teacher development (Zeichner & Noffke 2001) and school-based enquiry for knowledge creation at school level (Hargreaves 1999).

Professional Development on the Curriculum Workshops: Collaborative reflection and empowerment.

The Spanish Curriculum Workshop was designed also with a professional development dimension aiming to promote teachers' collaboration, reflection and empowerment. In the following, we trace these three aspects of teachers' development in the CW discourse and discuss them.

Collaboration in the CW: issues of Identity and Participation among innovative teachers.

Collaboration was a topic discussed during all the CW as having a critical impact on the development and success of school-based innovation. Throughout the CW, the innovative teachers' collaboration was from the very beginning very relaxed, easy-going and trustful in manner; they dealt with conflict in a successful way (for instance, when discussing about the need for effective leadership) and managed to achieve outcomes (the final document) in every meeting. From our viewpoint, apart from other clear contextual factors (the CW was not undertaken as part of their normal work in their schools), it also played a role in this successful collaboration the sense of *identity* that developed among the participating teachers.

Due to the purposeful sample necessary for the Spanish CW project, teachers knew from the beginning that they were going to collaborate with a group of innovative teachers who were also involved in school-based reform. In this sense, teachers were really excited about the fact of meeting other innovative professionals, because this was an opportunity to know how things work in other schools and contexts that are similar (in educational philosophy) to theirs:

> *C2: You feel like sticking your head out and breathing, don't you? And [seeing] what you are doing, what the other is doing, what I do … (Discourse during CW1)*

Teachers' connected from the beginning, asking questions to each other during the presentation of the "stories" of their innovations. They devoted their free time also to gaining more insights about each others´ experiences. It was clear, and one teacher stated so during the coffee-break time, that they were a group of atypical teachers and that it was not easy, ordinarily, to be in contact with

other professionals also interested in changing and improving their practice. A feeling of closeness, recognition of a particular identity or profile similar to all of them, was emerging. It was very valued by these teachers, as their feedback questionnaires later showed:

> *"[the most valuable issue in the curriculum workshop was] to establish contact with colleagues who are also fighting to bring innovation into their schools." Teacher B1, feedback questionnaire.*

The importance given by teachers to be able to collaborate with colleagues with whom they share their identity of "innovative teachers" can be easily understood if one takes into account the difficulties they generally find to collaborate with their school-based colleagues (the critical role given to collegiality and collaboration when discussing motivation and change).

> *"This sort of reflections [the ones that appeared throughout the CW] never go further away from the small group of innovative teachers, the ones interested in improve their practice, but the truth is that the reality in the schools is very different, there is an overwhelming individuality of the majority of the teaching staff." Teacher A2, feedback questionnaire.*

In this sense, it seems that the innovative teacher is a quite isolated professional, which perhaps is the reason why he or she struggles to achieve school-based innovation at school.

> *C1: in my case, I am the pusher of the innovation [in my school] due to a personal necessity of … of being able to share something with my colleagues! (Discourse during CW1)*

Despite the trustful atmosphere in which collaboration took place during the CW, in particular in the small-group work, it can not be said that equality in participation was ensured. It was difficult to have all teachers participating with the same level of activity. In general, teacher leaders played a more active role than their colleagues, in particular in aspects such as being a spokesperson for the presentation of the small-group results. We do not consider this to be due to hierarchical differences, which almost do not exist in the Spanish educational context, but with the following two factors. First, teacher leaders have more self-confidence about their educational ideas and are used to coordinate work with other teachers. Second, the teacher leaders were those more interested by the topics discussed during the meetings, because the knowledge being constructed was useful for them to support their innovations. Fortunately, due to the fact that many of the teachers present (5 out of 8) were actually teacher leaders, the majority of the teachers had an active participation and a broad range of views was discussed.

Reflection in the CW: From concreteness to abstractness and reflecting collaboratively.

The design of the Spanish CW tried to facilitate teachers' reflection by:

- Engaging teachers in a discourse about the process of school-based innovation, that is, discourse at the *meta* level.
- Going from the concrete experience (e.g. the teachers' narrative of the story of their innovation) to abstract concepts (e.g. what facilitates change in school-based innovation?)

Regarding reflection, teachers explicitly mentioned this process throughout their feedback writing, in particular referring to the outcomes of the CW as produced by this reflected process:

> *"The CW document is the product of our reflections" Teacher A2, Feedback questionnaire.*

It is also recognised by teachers to have achieved a certain level of depth and abstractness in their discussion, going from the known surface of their experience with school-based reform to the deeper level of the causes:

> *"we have reflected about aspects that I had never thought before about what causes them" Teacher D2, Feedback questionnaire.*

However, we must say that this step-by-step path, from concrete to abstract, was not followed by all teachers at the same level. For some of them, in general the non teacher leaders, it was difficult to engage actively in the discussion of "apparently" the same topics (motivation, change) but from the level of the causes (what facilitates, what makes it more difficult).

The reflection that took place in the Spanish CW´s was promoted to be "collaborative reflection". We refer to collaborative reflection, in contrast with personal reflection, as reflection which is undertaken collaboratively and would have not occurred without other people's direct or indirect intervention. Obviously, reflection being a cognitive function, we can only speak here of the reflection that can be identified from discourse and not about all the reflection that actually occurs during the CW's.

Collaborative reflection can be identified when teachers' are reflecting together so that the statements they agree upon do not belong to (could not have been produced by) or refer to (rely on the experience of) only a particular teacher, but to two or more participants in the group deliberating. In this sense, we categorise as discourse of collaborative reflection that discourse which is produced:

- collaboratively by two or more teachers adding personal or other people's reflective arguments to the creation of the same idea (collaborativeness);
- by one teacher mentioning arguments or ideas that refer to other people's experience which he or she happens to know (appropriateness).

We have identified collaborative reflection throughout the teachers' discourse in the Spanish CW basically thanks to the use of "1-agreed idea cards" in which teachers had to agree on a statement that embodies their different views and experiences on the issue. In the discussion to decide that statement, teachers either summed up their arguments (collaborativeness) or even referred to the experience of each other (appropriateness) to justify their statements. An example of a collaborative reflection, in this case of the latter form, can be found in the following dialogue:

> *B1: For me, the first [motivation] is the desire to solve a problem… you notice a problem and you try to solve it … with the innovation.,*
>
> *D2: yes, (yeah)*
>
> *B1: (don't you think so?) ((Addressing C2)) the case of the [science] language, ((addressing D2)) the case of the environment, ((pointing towards himself)) the case of the science classroom, isn't it?...*

In this example, teacher B1 uses the problems he knows teachers D2 and C2 had identified in their schools to reinforce their argument that innovation started with the desire to solve a problem. His reflection is not only based on his own experience, but also on the experience of others.

For this sort of collaborative reflection to occur in a discourse, we need a group which, among other characteristics: deliberate in a relaxed, trusting and friendly atmosphere; discuss issues relevant for all of them and where each participant knows each other's experience (regarding the issues discussed). In this sense, the identification of collaborative reflections in our CW's is significant for showing that the selection of participants, key questions and methodologies of our CW was adequate to support the afore mentioned characteristics in the produced discourse.

Empowerment as a result of the CW

As we have mentioned before, there are five qualities of teacher empowerment (Bybee's significance; knowledge, skills and attitudes; community; enjoyment and responsibility) that the participating teachers in the Spanish CW already held regarding school-based innovation. However, we have also identified

some sources of teachers' empowerment regarding these qualities due to teachers' participation in the actual CW approach.

Regarding knowledge and skills, teachers learned about the actual CW methodology. In their feedback questionnaires, teachers' were asked to discuss the CW as a useful strategy for themselves in other situations. They consider that the CW approach would be useful at the school level for deliberating about different issues regarding decision making, in particular in teacher meetings. However, they considered that the role of the facilitator/moderator is crucial for the development of the CW, which makes it difficult to be implemented.

Regarding community, the strong sense of identity and community that emerged throughout the CW between the innovative teachers has already been discussed. When asked to mention most relevant aspects about the CW approach, most teachers' mentioned issues of collaboration: to be able to meet and discuss with "equals", "Knowing others", "sharing views and experiences". This is related also with networking, which for some teachers extended to after EUDIST (Teachers C1 and A1 decided that their schools should further network after EUDIST, and they found possibilities to do so via another project

Some long term empowerment was also achieved by some teachers at individual level. For instance, teacher B1 decided after the process that he would like to focus his future PhD thesis on the study of the implementation of innovations, which he found really interesting to analyze and discuss.

Summary and conclusions

School-based reform has many forms and challenges teachers in various ways. Four examples of school-based innovation have been selected and described. Through these examples it has been shown the context in which school-based innovation takes place in Spain: a permissive but not encouraging context in which teacher leaders struggle with reform.

The Curriculum Workshop in the Spanish EUDIST project has gathered teachers and teacher leaders from these schools to engage them in a collaborative reflective dialogue about school-based innovation. In this deliberative and reflective scenario of the CW, the innovative teachers have dissembled their knowledge about the school-based reform process and have constructed a broader (collaborative) and deeper (reflective) version of it. The usefulness of this knowledge is for teachers' themselves to guide future practice, but also for educational policy-making and professional development design that support this bottom-up approach. In EUDIST, teachers have been

put at the centre of this knowledge-creation for bridging the gap between generation of educational knowledge and actual educational practice.

During the CW, teachers have discussed the motivating factors for school-based reform, together with the changes identified and their recommendations to educational stake-holders for supporting this process. The outcome of these collaborative reflections has been a collaboratively constructed innovative teachers' voice about the dimensions of motivation, change and support for school-based reform. This innovative teachers' voice captures the view of educational change that these professionals hold. It can be summarised as: *change which has school-dimension*; *change that is it desired* and *change that should be supported by an enquiry culture*.

The notion of *change with real school-dimension* embodies the struggling of teachers to involve their colleagues in a common project of reform which drives the school towards the achievement of "school identity". *Change that is desired* also discusses the critical role that innovative teachers give to collegiality in the school-based reform process. It also shows the particular view of professionalism of innovative teachers, which includes the notions of teaching as a life-long learning and problem-solving profession. Related with this latter, innovative teachers advocate for a *culture of enquiry* in education to support effective and reliable school-based change. Collaborative enquiry, evidence-based professional development and empirical results should play a major role in school change and decision-making.

The mentioned aspects of the innovative teachers' voice offer new insights to guide future action in this field, both for teachers' themselves and other educational stakeholders. For innovative teachers, school-based reform has to focus in change that is desired (born from dissatisfaction with current practice in a school where the professional culture of life-long learning and problem-solving is being built); a special effort has to be made in order to build school identity during the process (choosing innovations that could gather most school-teachers, encouraging that educational rationales become explicit to unify philosophy and discourse, opening the school to the community, networking with other schools with similar profiles, etc.) and both the previously mentioned aspects could be supported by a culture of enquiry (diagnosing problems, relying in empirically based results, using evidence-based materials and approaches, engaging in collaborative enquiry and practitioner research, etc.). In this sense, innovative teachers' ideas resonate to a great extend with some ideas of "good practice" and successful change present in the literature.

The Curriculum Workshop in Spain had also a professional development dimension aiming to promote participating teachers' networking and collaboration, reflection, deliberation and empowerment. Four metaphors for the teacher in school-based reform directed this approach: the teacher as a

knowledgeable agent; as a social agent in a community of practice; as a reflective agent and as an impelling-reform agent. The study of the CW approach as a professional development scenario for innovative teachers shows the emergence of a sense of identity among "innovative" teachers; the increasing presence of reflection which is truly collaborative in teachers' discourse, and a sense of empowerment that develops further through collaboration and networking. In this sense, the approach followed in the Spanish CW helps innovative teachers to face the isolation in which they generally develop their practice and to enrich their views with the views of "equals" in a developmental process based on collaborative reflection and knowledge construction (learning). We consider this helps innovative teachers to construct a professional image of him/herself as teacher leaders in reform, understanding better their practice, the contradictions inherent to it and the difficult territory in which they have to move.

7. Publication 3

Análisis del Contenido del Discurso Cooperativo de los Profesores de Ciencias en Contextos de Innovación Didáctica

Publication 3 of this compendium, which title in English is *"Content Analysis of Science Teachers' Cooperative Discourse in Contexts of Educational Innovation",* reports the results of a research undertaken by the author within the teachers' group *Scientia Ommibus*. This group of teachers is supported since its origin by the Association of Teachers Rosa Sensat (Associació de Mestres Rosa Sensat) and the Educational Institute ICE (Institut de Ciències de l'Educació), at the Universitat Autònoma de Barcelona. The participatory observation work reported in Publication 3, part of which was included in the authors' *Master Thesis* (Couso, 2002), belongs to the initial period of the group work (beginning of its second year) and lasted for one year. The author still continues belonging to this group, as a normal member.

Publication 3 analyses teachers' cooperative work in a scenario of bottom-up curriculum design by analysing the discourse teachers produce in the cooperation. The analysis done is a qualitative content analysis of the transcription of teachers' discourse during the group meetings, finding the content areas in which the discourse of the teachers has meaning. By using different quantitative analysis of the qualitative analysis done, the frequency, quantity and time-evolution of each type of discourse is obtained, allowing the identification of discourse distributions and patterns. These are related with special characteristics of the activities and composition of the group work. Some of these identified distributions and patterns, such as a discursive pattern around content knowledge (teachers exchanging knowledge of science) or a certain distribution of meta-cognitive discourse that guides the action, are related to desired professional development scenarios. In this sense, the detailed *micro* analysis of the cooperative discourse teachers produce when designing science education innovative curriculum reveals *macro* structures of discourse that are useful to identify the professional development potential of the curriculum innovation scenario.

Due to the fact that Publication 3 is published in Spanish, an extended abstract in English is provided. More information of this work in English is available in Annex 2.

Content Analysis of Science Teachers' Cooperative Discourse in Contexts of Educational Innovation

New reform contexts increasingly demand from teachers to be the leading actors of innovation, thus challenging teachers' learning and professional development. As a consequence, standing from a socio-cultural framework that relates social interaction with learning, teachers' cooperative work becomes a focus of interest. However, we know little about how science teachers work cooperatively for curriculum innovation, and particularly, how they develop professionally in those contexts.

This research has the aim to increase our knowledge in this field by doing a qualitative content analysis of teachers' discourse in cooperative scenarios. We analyse the discourse produced by a self-organised group of secondary-school science teachers when participating in curriculum design. The goal is to find the different distributions of teachers' discourse when involved in different activities of cooperative curriculum design, and explore the potential for teacher learning and development of these discourse distributions / activities.

To have an idea of the activities in which teachers are involved, teachers' meetings have been summarised and structured in *Activity Segments.* For the exploratory analysis of teachers' discourse, the types of discourse teachers use in these scenarios have been categorised in *Semiotic Spaces* and *Discursive Sequences. Semiotic Spaces* have been defined as the content-areas in which teachers' discourse has meaning. In our research study, three different Semiotic Spaces have been identified: *Didactical,* i.e. teachers' discourse about features of teaching, such as selection of content, teaching methodology, etc; *Scientific,* i.e. teachers' discourse within the science field; and *Cooperative*, i.e. teachers' discourse that acts upon cooperation, such as its management or regulation. While the first two are inherent to science teachers' discourse, the last one is context-dependant and characterises teachers' cooperation. *Discursive Sequences*, our analysis unit, are sequences of teachers' discourse that form meaningful units and refer to different features of reality within the same Semiotic Space. For instance, the selection of content and the classroom methodology belong to the same Didactical Space but refer to different features of it.

Apart from the qualitative identification of the content categories of teachers' discourse, a quantitative analysis of this data has been done. We have used two analytic and representational tools able to show the distribution *of* teachers' discourse for each meeting. *Histograms* show the total amount of a particular Discursive Sequence in a meeting, allowing easy comparison between general features of discourse in different types of cooperative meetings. *Thematic Clustering Graphs (TCG's)*, a tool adapted from the discourse analysis field, show the chronological evolution of teachers' discourse, providing information about *when* (in which type of Activity Segment) teachers speak about *what* (the particular Discursive Sequences of their speech).

The results of this analysis show interesting discursive patters in the cooperative work of teachers. For instance, both from the histograms and the TCG of the two meetings analysed it is identified the often and regular presence of metacognitive discourse along the teachers' meetings. This pattern can be related with the well-known Schön's "reflection-on-practice", but not regarding the practice of teaching but the practice of cooperative curriculum design within the studied teacher group. In this sense, from the discourse analysis done, the group is characterised as a reflective one. A second interesting discursive pattern identified is the difference in the presence and distribution of discourse in the scientific field along the different activities. In particular, when teachers are deciding what practical work they would include in their teaching unit, the presence of scientific discourse increases in a significant way when compared with other design situations. When going back to the qualitative data of teachers' discourse that correspond to these patterns, we see that in these discursive situations teachers' make explicit their scientific understandings and also their doubts regarding subject matter knowledge. This interesting discursive exchange on subject matter seems also related with the interdisciplinary character of the teachers' group and the materials they designed. This has implications regarding the consideration of the cooperative context analysed as a fruitful professional development scenario for teachers.

According to these results, this exploratory study of teachers' cooperative discourse offers a first description of the discourse teachers' use within a curriculum design setting. It also shows how the analysis of this discourse, in particular its distribution and discourse patterns, can be a useful tool for characterising teachers' cooperative work and identifying interesting professional development contexts

ANÁLISIS DEL CONTENIDO DEL DISCURSO COOPERATIVO DE LOS PROFESORES DE CIENCIAS EN CONTEXTOS DE INNOVACIÓN DIDÁCTICA

Couso, Digna y Pintó, Roser
Departament de Didàctica de les Matemàtiques i les Ciències Experimentals, Universitat Autònoma de Barcelona

digna.couso@uab.es
roser.pinto@uab.es

Resumen. Los contextos de reforma actuales demandan cada vez mayor protagonismo de los profesores en la innovación, lo que presenta un reto al desarrollo y aprendizaje docente. En consecuencia, desde un marco socio-constructivista en el que se vincula aprendizaje e interacción social, la cooperación entre docentes en estos contextos de innovación didáctica adquiere un nuevo interés. Sin embargo, es muy poco lo que sabemos de cómo los profesores trabajan y se desarrollan en estos entornos, vinculados en la literatura a la idea de comunidad profesional. Esta investigación tiene el objetivo de aumentar nuestro conocimiento en este ámbito a través del análisis del contenido del discurso docente en un entorno cooperativo natural y autogestionado. El análisis realizado, de carácter exploratorio, identifica los tipos de discurso propios de la cooperación docente, así como patrones discursivos interesantes por su potencial en el desarrollo y aprendizaje del profesor.
Palabras clave. Cooperación docente, desarrollo del profesor, aprendizaje del profesor, análisis del contenido, comunidad profesional.

Content Analysis of Science Teachers' Cooperative Discourse in Contexts of Educational Innovation

Summary. New reform contexts increasingly demand that teachers be the leading actors of innovation, thus challenging teachers' learning and professional development. As a result, from a socio-cultural standpoint that relates social interaction to learning, teachers' cooperative work becomes a focus of interest. However, we know little about how teachers work cooperatively for curriculum innovation and in particular, how they develop professionally in those contexts, which is related in the literature with the idea of Professional Community. This research is aimed at increasing our knowledge in this field through a content analysis of teachers' discourse in cooperative scenarios. The exploratory analysis done identifies the types of discourse and the discourse patterns present in these contexts, discussing their potential for the participating teachers' learning and development.
Keywords. Teacher cooperation, teacher development, teacher learning, content analysis, professional community.

CONTEXTO DE REFORMA Y NECESIDAD DE DESARROLLO PROFESIONAL: LA IMPORTANCIA DE LA COOPERACIÓN DOCENTE

En los contextos de reforma de las dos últimas décadas se han analizado diferentes posturas político-educacionales: desde la mera imposición externa de la innovación *(top-down* o de arriba abajo), por una parte, hasta la promoción de cierto autodesarrollo de escuelas y profesores *(bottom-up* o de abajo arriba), por otra. En didáctica de las ciencias, el trabajo pionero de Black y Atkin (1996) analizó procesos de reforma diversos mostrando que se obtiene un éxito mucho mayor cuando los profesores participan activamente en el diseño, planificación e implementación de las innovaciones. Resultados similares los obtuvo el proyecto internacional STTIS (Pintó, 2005), que evidenció que las transformaciones que realizan los profesores en las innovaciones propuestas de forma tradicional son «críticas». Éstos y otros resultados ponen de manifiesto la necesidad de que el profesorado cobre más protagonismo en las reformas educativas. En consecuencia, se reclama una cultura de asociacionismo y colaboración entre investigadores y docentes que reduzca la reconocida distancia entre investigación y práctica educativa (Fullan y Hargreaves, 1992; Little, 1993); se evidencia la importancia de promover sentido de propiedad y compromiso (Ogborn, 2002), así como autonomía, *empoderamiento* y liderazgo (Lieberman y Miller, 1991) de los profesores en la reforma y se reivindica la contextualidad de la innovación (Hargreaves, 1999).

En este contexto, las iniciativas de reforma que tienen en cuenta la perspectiva de «abajo arriba», constituidas en su mayoría en torno a la idea de establecer «colaboraciones de profesores» que actúen en la reforma, han ido creciendo en número, visibilidad e importancia (Little, 1993), sobre todo en el ámbito anglosajón. En la literatura aparecen como *comunidades de aprendizaje* (Grossman, Wineburg y Woolworth, 2001; Wilson y Berne, 1999), *comunidades de indagación* (Cochran-Smith y Lytle, 1999), *comunidades de práctica* (Barab y Duffy, 2000) o *comunidades profesionales* (Stoll, Bolam, Mcmahon, Wallace y Thomas, 2006). En todas ellas la clave reside en la idea de comunidad, diferenciada en la literatura de un simple grupo de docentes (Grossman *et al*., 2001). A pesar de la diversidad de teorías sobre comunidades disponibles en educación, en su revisión Westheimer (1998) menciona cinco características *sine qua non*: interdependencia, participación o interacción activa, intereses compartidos, preocupación por los puntos de vista individuales o minoritarios y relaciones personales significativas.

Las iniciativas de «comunidad» mencionadas se plantean en la literatura como estrategia de reforma curricular no sólo porque favorecen la innovación desde la escuela, sino porque se considera que favorecen el aprendizaje, autonomía y *empoderamiento* de sus participantes, lo que influencia su desarrollo profesional. En su origen, Lord (1991) sitúa las comunidades dentro de un programa de desarrollo profesional alternativo que involucra el aumento del conocimiento de los profesores, pero también el liderazgo o protagonismo en la reforma y el acceso de los profesores a una red amplia de relaciones profesionales. En el ámbito de la didáctica de las ciencias, los autores Bell y Gilbert elaboran un influyente modelo de desarrollo del profesor en el que también se interrelacionan las dimensiones profesionales, personales y sociales, enfatizando estas últimas (1994; 1996). Para los autores la enseñanza, aunque supuestamente una actividad individual, *«se practica en una arena pública y es una actividad social gobernada por reglas y normas»* (p.13). En consecuencia, consideran el desarrollo profesional docente como un proceso complejo que opera tanto dentro como fuera del aula. El objetivo ya no es el desarrollo del profesor para ser mejor docente *en el aula*. En este marco, ser mejor docente implica además ser mejor miembro de una colectividad profesional que también trabaja fuera del aula, de la que se espera que diseñe, implemente, reflexione, evalúe, gestione, decida, innove… Y que realice estas acciones en un entorno profesional social

En consecuencia, para poder participar activamente en procesos de reforma que otorgan un mayor protagonismo al profesorado, los docentes deben desarrollar la competencia de trabajo cooperativo (Valcárcel y Sánchez, 2000). El interés en la cooperación docente no es por motivos meramente organizativos. En los procesos de reforma el aprendizaje del profesorado es clave (Ball y Cohen, 1999) y desde la perspectiva sociocultural en la que nos situamos, el aprendizaje se considera un proceso social que se produce en la interacción. Aunque los estudios sobre aprendizaje docente han sido criticados por no aportar suficientes datos sobre qué y cómo aprenden los profesores en las oportunidades formativas que se les presentan (Bransford, Brown y Cocking, 2000; Wilson *et al*., 1999), es común en la literatura la asunción de que el conocimiento que tenemos sobre aprendizaje de los alumnos es válido también para los profesores. En este sentido, se ha destacado el valor de la colaboración y el trabajo en comunidad para el aprendizaje docente (Bransford *et al*., 2000), debido a que a pesar de cierta controversia respecto a las ganancias cognitivas en alumnos, *«los trabajos que dan cuenta de diferencias significativas a favor de la cooperación casi duplican los que postulan la ausencia de distinciones en un sentido u otro»* (Rodríguez-Barreiro y Escudero, 2000). En este sentido, la competencia de trabajo cooperativo docente que resulta de interés no es la mera capacidad de «trabajar juntos», sino la capacidad de participar en interacciones sociales que producen conocimiento profesional y de internalizar ese conocimiento. O dicho de otro modo, la capacidad de aprender en estos entornos.

LA COOPERACIÓN A TRAVÉS DEL DISCURSO: DEFINIENDO LAS PREGUNTAS DE INVESTIGACIÓN

Desde la perspectiva sociocultural el aprendizaje es visto como un proceso social en el que el lenguaje desempeña un papel decisivo como mediador de la acción. No es de extrañar, por tanto, el creciente interés en didáctica de las ciencias por el lenguaje, en particular su papel en la construcción de conocimiento científico en el aula de ciencias (Fensham, 2004; Lemke, 1997). Desde el marco del análisis del discurso, la noción central es que el lenguaje debe ser entendido como «acción» y «afiliación» (Gee, 1999). Es decir, las principales funciones del lenguaje son mediar la actividad humana y mediar la afiliación de las personas a los grupos sociales, en contra de la visión de lenguaje como mera «comunicación de información». A este lenguaje que media las acciones y afiliaciones, el «lenguaje-en-uso», es a lo que denominamos *discurso*. De acuerdo con esta visión, la relación entre discurso y situación o contexto es compleja. Por un lado, las personas construimos un discurso (un lenguaje-en-uso) adecuado, es decir, adaptado a las situaciones o contextos. Por otro lado, éste discurso, a su vez, crea las propias situaciones o contextos a los que se adapta. Es decir, el discurso «da forma» a la situación que «da forma» al discurso. Entender el discurso a la vez como causa y consecuencia de la situación o contexto, de las acciones que se producen y de la red de afiliaciones sociales que existen implica que el discurso constituye en sí mismo un foco de interés investigativo: no es sólo un medio para acceder a los aspectos de la realidad social que se «esconden» tras él (Gill, 2000). Así, el discurso de los docentes no es sólo producto de, sino que también genera la situación de cooperación docente en la que estamos interesados, por lo que analizarlo es de gran importancia para caracterizarla y comprenderla.

Nuestro interés por el discurso no sólo está relacionado con el discurso por la situación o contexto de diseño curricular cooperativo, sino también por lo que nos dice

de los participantes, en particular de su pensamiento, en esta situación. Desde el paradigma socio-constructivista en el que nos situamos, compartimos la idea del lingüista ruso Bakhtin de 'voz' como *consciencia hablante del individuo* (Wertsch, 1993) que expone el pensamiento de una persona. En la interacción, las diferentes «voces» de los participantes se exponen y se influyen mutuamente. En este sentido, nos interesamos por lo que los docentes dicen en el seno de la interacción (el contenido de su discurso) porque lo consideramos conectado con lo que *piensan* en la interacción y con cómo estos pensamientos se modifican en el transcurso de la interacción. Obviamente, no todo lo que los profesores piensan puede inferirse de su discurso. Aun así, nos resulta de interés identificar lo que los profesores escogen decir en el contexto de su trabajo cooperativo de diseño curricular.

En el trabajo que presentamos nos proponemos como objetivo explorar el discurso de los profesores en entornos cooperativos de innovación didáctica cercanos a nuestra idea de comunidad profesional, para explorar el fenómeno de la cooperación docente en estos entornos y su relación con el aprendizaje y desarrollo del profesor. Al tratarse de un estudio de carácter exploratorio y descriptivo, como primera aproximación nos proponemos caracterizar el discurso cooperativo docente desde el punto de vista de su contenido temático, es decir, nos preguntamos de qué y cómo «hablan» los docentes cuando realizan diseño curricular de forma cooperativa. De acuerdo con la perspectiva discursiva presentada, nuestro interés en el contenido del discurso, en las áreas de contenido del mismo, proviene de entenderlas como las áreas que a la vez generan y son producto de la situación de diseño curricular cooperativo estudiada. Así, nuestras preguntas de investigación son: ¿cuáles son las áreas de contenido del discurso cooperativo docente, es decir, las áreas de contenido que son producto y a la vez generan esa situación de diseño curricular cooperativo? y ¿qué nos dicen las características de estas áreas de contenido (su frecuencia, cantidad, posibles patrones discursivos) de la actividad de diseño cooperativo docente que están mediando y de su potencial para el desarrollo docente?

CONTEXTO DE LA INVESTIGACIÓN

A pesar de la gran influencia de la visión socio-constructivista del aprendizaje en el ámbito educativo, la interacción y la cooperación docente es muy poco frecuente como metodología de trabajo, generación de conocimiento didáctico y desarrollo profesional. Las experiencias de colaboración que se producen en los centros son generalmente escasas, rutinarias y sobre aspectos básicamente organizativos. En general se habla de «soledad» y «aislamiento» docente, en ocasiones escogido por el propio profesorado como condición de autonomía, creatividad o eficacia (Perrenoud, 1995). No es de extrañar, por tanto, que la literatura en esta área corresponda en su mayoría a investigaciones sobre desarrollo profesional en comunidades de aprendizaje impulsadas por los propios investigadores interesados en el fenómeno (Wilson *et al.*, 1999).

Puesto que sabemos muy poco sobre estas situaciones de «comunidad» y de cómo se produce la cooperación docente para el aprendizaje, el desarrollo profesional y la innovación didáctica, estos estudios en contextos no naturalistas han resultado de gran interés. Sin embargo, los ejemplos de experiencias de trabajo cooperativo no vinculadas estrictamente a procesos de reforma «formales», como son los grupos de innovación de profesores, constituyen un contexto más privilegiado para el estudio de la comunidad profesional que debería ser analizado también. En uno de estos grupos de profesores es donde se realiza esta investigación.

El grupo *Scientia Ommibus*[1] es un grupo de profesores de ciencias de secundaria que trabajan cooperativamente en el diseño curricular de unidades didácticas sobre el tema de la energía. Su objetivo es generar una batería de recursos de aula como ejemplificación y desarrollo de su forma de entender la enseñanza y aprendizaje de las ciencias: enfoque integrado (física, química, biología), contextualización CTS, inclusión de las TIC's y especialmente uso de diferentes metodologías interactivas en el aula.

La característica más importante de este grupo con respecto a la investigación realizada es el hecho de que se trata de un grupo interescolar de diseño curricular voluntario, autoconstituido y autogestionado, que por tanto constituye un contexto natural apropiado para el análisis de la cooperación docente escogida y vinculada al auto y codesarrollo (Terhart, 1999). La formación del grupo se origina en torno al coordinador, Roger, profesor de biología con amplia experiencia didáctica en el aula y como formador de profesores. Manel y Joan son profesores de biología que colaboran con él desde hace años, teniendo también amplia experiencia docente y formadora. Susanna (profesora joven) y Júlia (profesora con experiencia) se han incorporado el año anterior y son profesoras de química. Pep es físico e ingeniero y actualmente no es profesor en ejercicio. En el momento en el que se realiza esta investigación, el grupo tiene un año de duración y ha elaborado un primer bloque de materiales didácticos sobre el uso de la energía. La forma de trabajo del grupo es a través de reuniones presenciales mensuales de unas 2:30 h a lo largo del curso escolar, además de interaccionar habitualmente mediante correo electrónico.

METODOLOGÍA DE LA RECOGIDA Y ANÁLISIS DE LOS DATOS

La recogida de datos se realizó con un enfoque etnográfico mediante observación participante de la primera autora, con el objetivo de aportar validez semántica al análisis (Krippendorf, 2004). El discurso verbal generado en las reuniones fue grabado en audio y transcrito. Se tomaron notas de observación y se recogieron los documentos escritos y demás materiales usados en las reuniones. Los datos que se presentan en este artículo corresponden a dos reuniones presenciales alternas (reuniones segunda y cuarta) de las seis realizadas a lo largo del curso, escogidas de forma conveniente porque muestran patrones discursivos interesantes para nuestro estudio.

En un primer nivel de análisis, las reuniones se estructuraron usando un constructo basado en los Segmentos de Actividad (SA) (Stodolsky, 1991) o los Segmentos de Interactividad (Coll, 1998; Márquez, 2002), utilizados en estos trabajos para identificar las «unidades de actividad» del aula, que han sido readaptados aquí a la situación de cooperación entre docentes. Los SA en los que se dividen las reuniones vienen determinados por el tipo de actividad que ocupa a los docentes en su trabajo cooperativo de innovación didáctica (Figura 1). La utilidad de este primer análisis no temático viene dada por la necesidad de estructurar las reuniones en acciones a las que poder vincular los tipos y patrones de discurso concretos que se identifiquen en el análisis.

Figura 1
Segmentos de Actividad (SA) identificados en las reuniones de los profesores.

Segmentos de Actividad	
Discutir y evaluar conjuntamente una propuesta interna	elaborada antes de la reunión y previamente presentada
	surgida espontáneamente en el transcurso de la reunión
	pendiente de discusiones de reuniones anteriores
Demandar o aportar una explicación / conocimiento declarativo	
Presentar, discutir y evaluar la idoneidad de un material externo	
Presentar y discutir actividades experimentales	
Poner al día o informar del estado de la cuestión	
Recapitular el trabajo realizado / definir las tareas pendientes / perspectivas futuras	
Otras / inclasificables (compartir experiencias personales, anécdotas, etc.)	

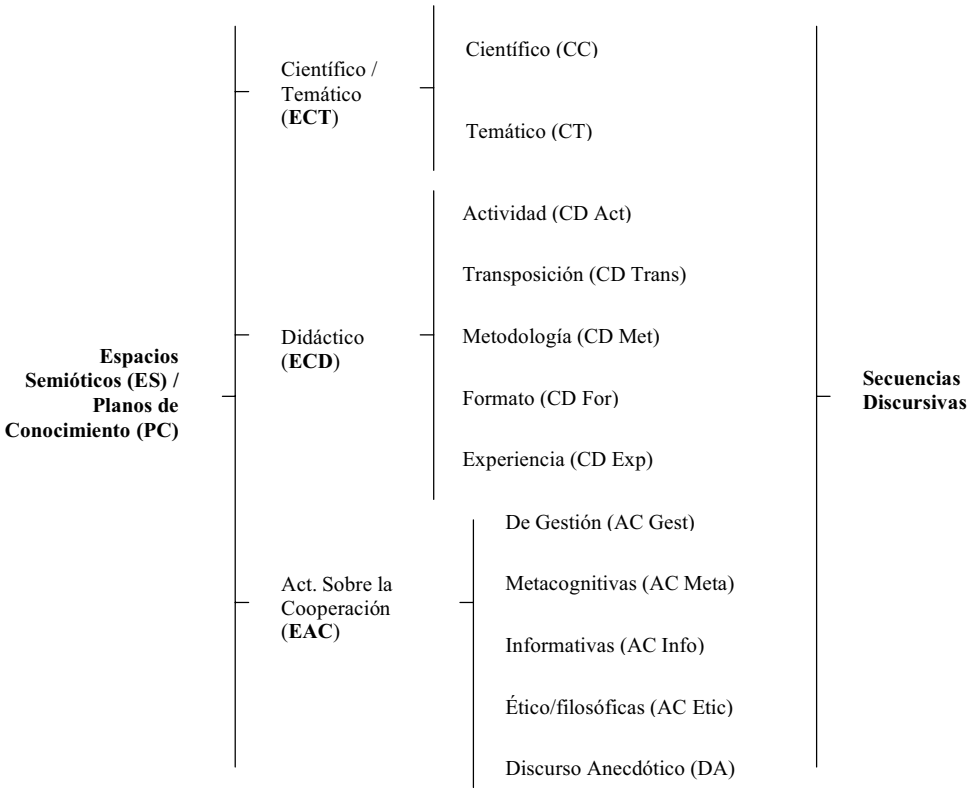
Para responder a la pregunta de investigación planteada sobre el contenido temático del discurso docente, realizamos un Análisis Cualitativo del Contenido (ACC) (Holsti, 1969; Krippendorf, 2004). Para la categorización tratamos el discurso generado en la cooperación como un producto global y continuo, prescindiendo de la división natural en turnos de palabra. El proceso de definición de las categorías de contenido del discurso se realizó de forma recursiva en un «ir y venir» de las categorías a los datos. Una vez definidas, la categorización de la totalidad del discurso docente de las diferentes reuniones se realizó por el investigador principal y observador participante. Para otorgar fiabilidad al análisis de los datos, muestras representativas de los mismos fueron codificadas por otros dos investigadores de forma independiente.

Un primer nivel de ACC identifica en el discurso de los docentes tres grandes áreas de contenido mutuamente excluyentes: didáctica, científica-temática y de actuación sobre la cooperación. Las dos primeras tratan sobre el «qué» del discurso mientras la última corresponde al «cómo» de la cooperación y opera sobre ésta: opina, guía, modula, gestiona. A nivel teórico, interpretamos estas áreas de contenido identificadas empíricamente desde dos puntos de vista diferentes, ambos compatibles con el análisis y coherentes con nuestro marco. Así, podemos entender estas grandes áreas de contenido como Espacios Semióticos[2] (Márquez, 2002), es decir, como los diferentes espacios de significado en los que tiene sentido el discurso. O bien como los Planos de Conocimiento en los que los profesores se sitúan al hacer sus verbalizaciones en el seno de la interacción cooperativa, es decir, en base a los conocimientos que los docentes utilizan, consciente o inconscientemente, en su discurso. Los espacios semióticos (ES) y los planos de conocimiento (PC) corresponden a dos maneras diferentes de mirar el discurso de los docentes para interpretarlo. Mientras la primera se limita a describir y caracterizar el discurso docente en la situación de cooperación, la segunda tiene implicaciones cognitivas explícitas, al considerar que el discurso nos da indicios sobre el conocimiento de los profesores y cómo lo usan en el contexto estudiado.

En el segundo nivel de ACC identificamos subcategorías que denominamos Secuencias Discursivas (SD), nuestra unidad real de análisis. Definimos una SD como un fragmento secuencial del discurso de los profesores que conforma una unidad de significado conjunta y que se diferencia de otras SD en que hace referencia a aspectos diferentes de la realidad en el seno de un mismo espacio o en la que los docentes que la producen apelan a tipos de conocimientos diferentes dentro de un mismo plano. Por ejemplo, dentro del mismo ES didáctico se identifican SD que tratan del contenido a enseñar (CD Cont) mientras que otras versan sobre metodología de enseñanza (CD Met). En la figura 2 se muestran los diferentes espacios semióticos o planos de conocimiento en los que se sitúa el discurso docente y sus correspondientes secuencias discursivas, identificadas empíricamente.

Una vez categorizado cualitativamente todo el discurso docente según las categorías de la figura 2, hemos profundizado en nuestro análisis utilizando dos herramientas de análisis cuantitativo de datos cualitativos, los histogramas de frecuencia y cantidad de discurso y las Graficas de Encadenamiento Temático (GET), que describimos a continuación.

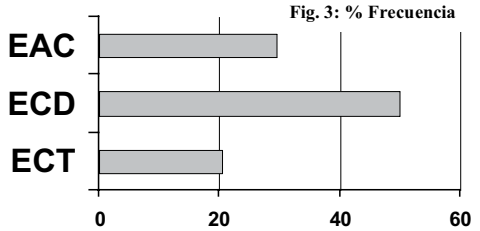
Figura 2
Espacios Semióticos y Secuencias Discursivas en el discurso cooperativo docente.

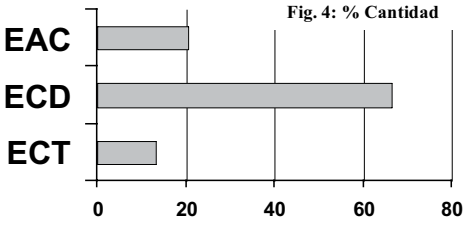


Los histogramas de frecuencia discursiva muestran la frecuencia total (en %) con la que una SD particular aparece en cada reunión, es decir, el número de veces en el que el discurso de los docentes se realiza desde uno de los planos de conocimiento o tiene sentido en uno de los espacios semióticos identificados. Los histogramas de cantidad de discurso grafican la cantidad total de discurso (en %) de cada SD en una reunión, medido en caracteres de discurso transcrito.[3] Ambos histogramas nos dan información estática sobre la relevancia, en términos de presencia, de unos tipos de discurso u otros en el seno de una reunión concreta.

Figuras 3 y 4
Histograma de % de Frecuencia y % Cantidad de discurso, respectivamente, de cada Espacio Semiótico (ES) / Plano de Conocimiento de la reunión 2.

Reunión 2: Seleccionando del contenido de las unidades didácticas.





Las figuras 3 a 6 muestran los histogramas de frecuencia discursiva (Figuras 3 y 5) y cantidad de discurso (Figuras 4 y 6) de cada uno de los espacios/planos identificados en las reuniones analizadas. Las figuras 7 a 10 nos muestran, de nuevo en tanto por ciento de frecuencia y cantidad de discurso, las secuencias discursivas (SD) más relevantes.

Figuras 5 y 6
Histograma de % de Frecuencia y % Cantidad de discurso, respectivamente, de cada Espacio Semiótico (ES) / Plano de Conocimiento de la reunión 4.

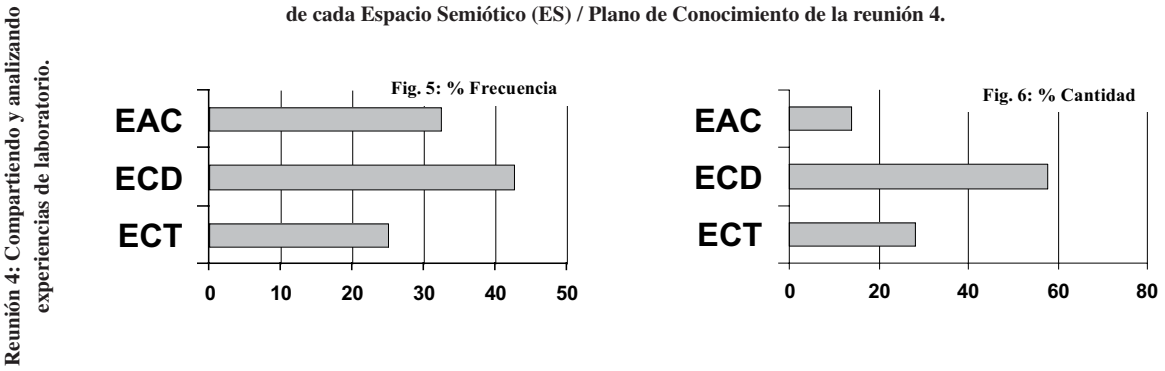


Figura 7
% de Frecuencia de cada Secuencia Discursiva de la reunión 2.

Figura 8
% de Cantidad de discurso en cada Secuencia Discursiva de la reunión 2.

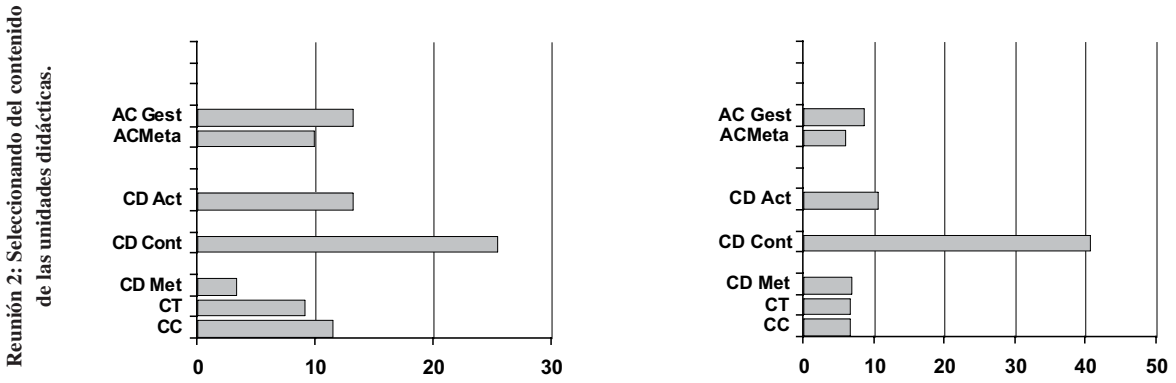
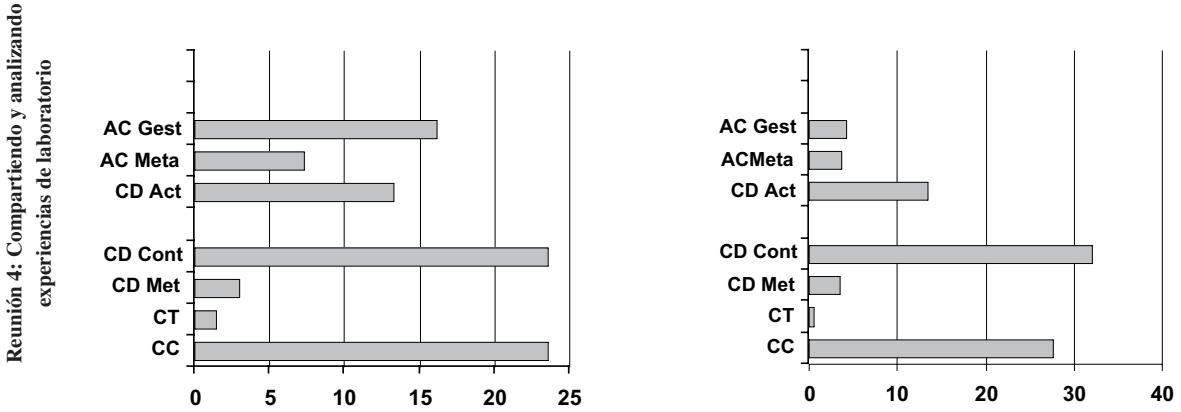


Figura 9
% de Frecuencia de cada Secuencia Discursiva de la reunión 4.

Figura 10
% de Cantidad de discurso en cada Secuencia Discursiva de la reunión 4.



Las Gráficas de Encadenamiento Temático (GET) son un instrumento de análisis del discurso que permite representar la dinámica de un diálogo extenso en una única figura que respeta la evolución temporal de esta dinámica. Este instrumento fue desarrollado para el análisis del discurso mediático y utilizado en educación para el análisis del discurso de docentes en formación por Angulo (2002). Para esta investigación, la adaptación que hemos realizado de las GET muestra la secuencia cronológica de cada SD y su «peso» (en cantidad de discurso). Es decir, se grafica para cada SD la categoría a la que pertenece (en vertical) y la cantidad de discurso de la misma (anchura horizontal), en el orden cronológico en el que se produce a lo largo de la reunión.[4] Así, las GET no solamente nos proporcionan una idea de la evolución del contenido del discurso según transcurre la reunión (por ejemplo, indicando cuál es el contenido del discurso al inicio o al final; ayudando a identificar posibles patrones discursivos de variación de contenido; señalando puntos de «inflexión» o de cambio abrupto en el discurso respecto al contenido, etc.) sino también de la relevancia, relacionada aquí con cantidad de discurso. Las figuras 11 y 12 muestran las GET de las reuniones 2 y 4 analizadas.

Figura 11

Evolución de la cantidad del discurso de cada Secuencia Discursiva emitido a lo largo de la reunión 2.

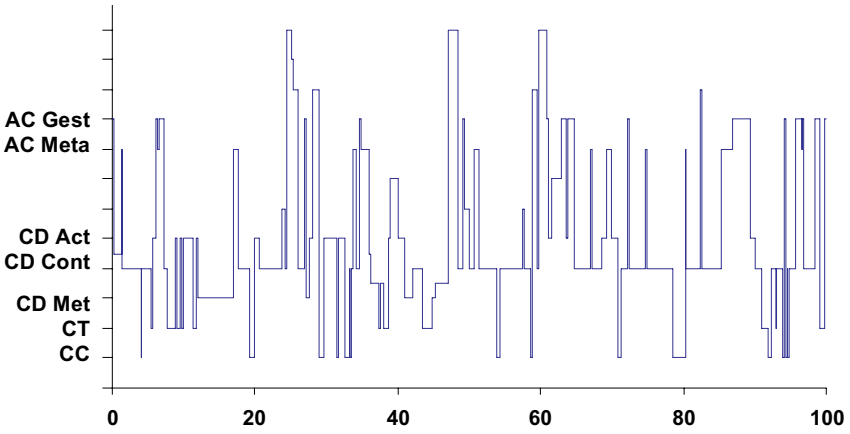
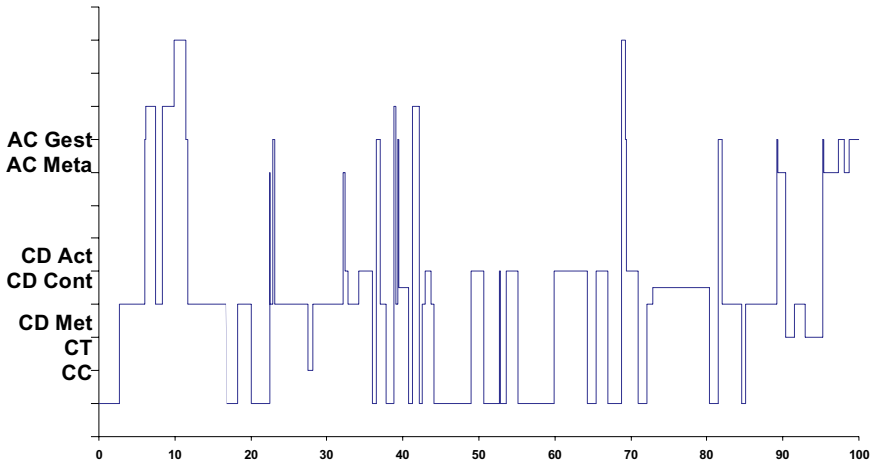


Figura 12

Evolución de la cantidad del discurso de cada Secuencia Discursiva emitido a lo largo de la reunión 4.



Leyenda figuras 11 y 12

Gráficas de Encadenamiento Temático de las reuniones 2 y 4.

En el eje vertical se sitúan las categorías o tipos de Secuencia Discursivas (SD) más relevantes identificadas en el análisis del contenido del discurso cooperativo docente. El eje horizontal representa, en tanto por ciento, la cantidad de discurso (medido en número de caracteres) de cada SD. En la gráfica se representan, cronológicamente de derecha a izquierda, el tipo y la duración de cada una de las SD en las que hemos categorizado el discurso de los docentes. La unión entre líneas horizontales y verticales no tiene significado.

DISCUSIÓN DE LOS RESULTADOS

En un estudio exploratorio del contenido del discurso cooperativo docente como el realizado, nuestros primeros resultados son las propias categorías y subcategorías de análisis identificadas empíricamente: los Espacios Semióticos (ES) o Planos de Conocimiento (PC) así como los tipos de Secuencias Discursivas (SD) de la figura 2. Esas categorías constituyen resultados esperables: el ES de Actuación sobre la Cooperación, aunque no identificado previamente en el discurso docente, sí aparece en investigaciones sobre aprendizaje cooperativo de los estudiantes como «*habla orientada al desarrollo de la dinámica grupal*» (p. 262) (Rodríguez Barreiro y Escudero Escorza, 2000); los ES Científico-Temático y Didáctico, por su lado, son habituales en el discurso de los docentes de secundaria de ciencias (Mellado, 1996). A continuación discutimos los resultados de cada una de estas categorías, respectivamente.

Resultados respecto del discurso de Actuación sobre la Cooperación

La lectura de los histogramas de frecuencia (Figuras 3 y 5) evidencia el peso nada despreciable, de aproximadamente un tercio de las intervenciones, que tiene el discurso del espacio de actuación sobre la cooperación (EAC). Aunque la presencia en cantidad de discurso (Figuras 4 y 6) es mucho menor (se trata de intervenciones escuetas) su presencia no es anecdótica sino regular. Estos resultados coinciden con los de Rodríguez-Barreiro y Escudero (2000) en su estudio de la cooperación entre estudiantes, donde este tipo de discurso tiene un peso también de aproximadamente un tercio de las intervenciones. Al igual que en ese estudio con estudiantes, en la cooperación docente vemos que se actúa sobre la cooperación para mantenerla.

Pero ¿qué tipo de discurso es exactamente este discurso de actuación sobre la cooperación? Según los resultados de los histogramas de secuencias discursivas (Figuras 7 a 10) se trata sobre todo de discurso de tipo organizativo o de gestión del grupo (AC Gest) pero también de discurso categorizado como metacognitivo (AC Meta). Este último resulta de gran interés, al ser un discurso no necesario a priori, pero que puede tener una gran influencia en la actividad del grupo, puesto que es un discurso que reflexiona explícitamente sobre ésta. Desde Schon (1983), la importancia de la reflexión en la práctica docente (en el aula) ha sido ampliamente discutida por muchos autores. Aquí encontramos un análogo, reflexión sobre la práctica docente *fuera del aula*, sobre el trabajo entre profesores. De acuerdo con nuestro marco de desarrollo profesional en el que consideramos que los docentes deben «expandir» su competencia profesional de la actividad aislada de «enseñar ciencias» a la actividad de cooperar para ser agentes directos en la reforma educativa, la aparición de este tipo de discurso resulta enormemente sugerente.

En los ejemplos de reunión que mostramos se identifican dos patrones de uso de este discurso metacognitivo muy diferentes, tal y como puede observarse en las GET de las figuras 11 y 12. En la reunión 2, el discurso metacognitivo es frecuente y aparece regularmente a lo largo de toda la reunión. En la reunión 4, por contra, el discurso metacognitivo es poco frecuente y aparece básicamente condensado en un par o tres de SD al final de la reunión. Además, se observa un patrón de intercambio entre discurso de gestión y metacognitivo, mediante SD de tamaño considerable, hacia el final de ambas reuniones.

Para poder interpretar estas características y patrones del discurso cooperativo docente singularizadas en las GET, necesitamos relacionar el discurso con los Segmentos de Actividad (SA) y los datos cualitativos. En la reunión 2, el discurso metacognitivo emitido sucede en SA no específicamente vinculados a la reflexión, del tipo «discutir y evaluar conjuntamente una propuesta» (ver Figura 1). Esto indica que en estas SD la metacognición forma parte de la actividad misma (de discutir y evaluar una propuesta). Por tanto, se trata de «reflexión en la práctica» pero en este caso, no de forma subconsciente y en la práctica docente de aula sino de forma explícita y en la práctica de trabajo cooperativo de innovación didáctica de los profesores. En este sentido, así como se considera que el profesor aprende y desarrolla su conocimiento profesional en parte en su reflexión «en la práctica», podemos pensar que este patrón de discurso (discurso metacognitivo puntual a lo largo de la actividad e integrado en SA no propiamente metacognitivas) podría relacionarse con el desarrollo del grupo de profesores con respecto al conocimiento profesional de diseñar cooperativamente. A nuestro modo de ver, sería de gran interés explorar este tipo de situaciones discursivas en el futuro, por lo que nos pueden decir sobre el desarrollo del profesor sobre la cooperación. Por el contrario, el patrón de discurso metacognitivo y de gestión del final de ambas reuniones media un SA propiamente de ese tipo: «Recapitulación del trabajo realizado y tareas pendientes», que parece natural de cualquier situación de trabajo en equipo con una cierta organización y, por tanto, es un tipo de patrón del cual no podríamos deducir que un ejemplo concreto de cooperación es reflexivo.

Las transcripciones nos ayudan a corroborar esta diferenciación que los patrones de discurso indican. La primera cita corresponde a discurso metacognitivo que vinculamos con «reflexión en la práctica» de la reunión 2.

Roger: […] nosotros somos buitres, ¿no? Que vamos, nos vamos acercando, olemos y entonces nos vamos acercando, […] pero finalmente llegaremos a, a la comida. Quiero decir, que esto es un primer vuelo, ¿no? Y en todo caso las aproximaciones las iremos haciendo cuando nos pongamos [a diseñar la actividad en concreto]

La segunda cita corresponde a discurso metacognitivo de tipo organizativo de la reunión 4.

Roger: Lo que sí que sería necesario antes de publicar nada sería, esto sí, que nosotros lo que generamos, alguien lo haya experimentado, ¿no? Esto sí que sería interesante porque si no no deja de ser una propuesta que está bien, pero es como un libro de texto, ¿no? Que los autores no saben cómo funciona.

Resultados respecto del discurso Didáctico y Científico

Los Espacios Semióticos/Planos de Conocimiento didáctico y científico/temático son, a priori, los espacios/planos

propios del discurso docente. Como sería de esperar, el discurso didáctico es el discurso más abundante en la cooperación docente de innovación didáctica, tanto en frecuencia como en cantidad de discurso. Según los datos de las figuras 4 y 6, el espacio didáctico constituye aproximadamente el 67% en cantidad del discurso para la reunión 2 y un 58% para la 4. Sí existe una diferencia muy significativa entre ambas reuniones en cuanto a la cantidad de discurso científico-temático. A pesar de mostrar frecuencias similares, en cantidad este discurso constituye apenas un 16% en la reunión 2, frente a un 28% en la 4. Debido al interés que respecto del desarrollo y aprendizaje de los profesores de ciencias puede tener que su discurso se haga en el espacio científico, generalmente obviado, consideramos interesante profundizar en estos resultados. Si miramos ahora la distribución en subcategorías de estos discursos (Figuras 8 y 10), encontramos similitudes entre la distribución de SD del espacio didáctico para las dos reuniones, pero diferencias muy significativas en el espacio científico/temático.

Con respecto al discurso del espacio didáctico (ECD), la SD significativamente más frecuente y abundante es el discurso didáctico del contenido (CD Cont). Esta categoría hace referencia al discurso sobre qué enseñar y está vinculada a la selección de los contenidos. Ocupa un 40% del discurso de la reunión 2 y más de un 32% de la 4. Si nos fijamos en la distribución de este discurso a lo largo de las reuniones en las GET de las figuras 11 y 12, vemos que de hecho el discurso CD Cont vertebra toda la reunión 2 y parte importante de la 4, aunque en ésta se identifica una interrupción del dominio de este discurso entre el 40% y el 70% de discurso emitido. Este periodo corresponde a un patrón discursivo concreto entre discurso didáctico de actividad y discurso científico, que discutiremos más adelante.

La alta presencia del discurso CD Cont en la reunión 2 es fácilmente interpretable teniendo en cuenta que esta reunión ocurre durante la primera etapa del trabajo de diseño curricular, en la que la decisión más importante a tomar hace referencia a la selección de los contenidos. Sin embargo, es interesante analizar por qué se mantiene como un discurso predominante también en la reunión 4, en la que los contenidos a tratar deberían estar seleccionados y el énfasis debería situarse en cómo enseñar estos contenidos (discursos sobre actividad o metodología). Esta «anomalía» en la evolución esperada del discurso docente nos indica la dificultad del grupo para definir los contenidos de la unidad.

Los datos transcritos nos sirven para ofrecer una interpretación de los motivos de esta situación, que consideramos están vinculados a una característica de la composición del grupo: ser un grupo interdisciplinar y poco balanceado entre disciplinas. Los profesores más expertos del grupo son profesores de biología, pero en las reuniones analizadas se está tratando de seleccionar contenidos básicamente de física y química[5]. En el discurso de los docentes se hacen evidentes sus dudas al respecto, en particular debido al enfoque de contextualización que los profesores utilizan:

Roger: […] desde el punto de vista de ciencias naturales somos modernos en el enfoque, pero no en los contenidos […] en cambio pienso que un [profesor] de física y química que se mire esto dirá que somos modernos tanto en el enfoque como en los contenidos […] A mí me gustaría también que contenidos del currículum [de física y química] los podamos trabajar de esta forma… es decir, la potencia, el trabajo, la energía, ¿es posible que salgan aquí en algún sitio?

A nuestro modo de ver, esta dificultad con la selección de los contenidos no es negativa si tenemos en cuenta el objetivo formativo y de desarrollo docente que asociamos a la cooperación. En esta comunidad de trabajo interdisciplinar que diseña materiales también con este enfoque, los profesores se replantean y cuestionan abiertamente qué enseñar y en qué secuencia hacerlo para mejorar el aprendizaje de los alumnos, lo que es de gran interés para el desarrollo docente.

Roger: [la potencia] es un concepto muy cotidiano, ¿no? Yo me acuerdo, yo tengo un calefactor de 1.500 vatios.
Júlia: síii.
Roger: y me acuerdo y sé que esto es potencia, ¿no? Que por tanto en el fondo hay una energía invertida ahí.
Joan: pero es difícil, es difícil porque…
Roger: Joan, pero si hacen cosas más complicadas en física y química […]
Pep: a ver, tú quieres introducir los conceptos de energía cinética, energía potencial, energía…
Roger: no, no, esto no me interesa.
Júlia: no, él dice sólo potencia y energía… el vatio, el kilovatio, el joule y ya está. Lo que tenemos en los aparatos eléctricos.
Roger: si es que es adecuado aquí, si es adecuado, a mí me parece interesante hacerlo aquí, porque nadie lo hace a través de aquí (señala los aparatos eléctricos).

El potencial del entorno interdisciplinar en el desarrollo y aprendizaje docente cobra aún mayor relevancia cuando se refiere al aprendizaje de contenidos científicos propiamente dichos, sobre todo respecto a las disciplinas científicas en las que los docentes no se formaron inicialmente pero que necesitan dominar. Los nuevos currículums, que desdibujan la disciplina clásica (enfoques de ciencia integrada, CTS, alfabetización científica, ciencia para la ciudadanía), necesitan profesores con amplios conocimientos científicos. En este sentido, sería interesante identificar qué situaciones o actividades de diseño cooperativo docente producen un patrón discursivo en el que se favorece el desarrollo en este ámbito. Si nos fijamos en los resultados del análisis del discurso realizado con respecto al discurso en el espacio científico-temático (ECT), se identifica una gran diferencia entre las reuniones 2 y 4 (Figuras 8 y 10). Mientras que para la reunión 2, en la que se deciden los contenidos de la unidad, la cantidad de discurso en este espacio es pequeña (un 12%) y está dividida a partes iguales entre las categorías temática y científica, en la reunión 4 prácticamente la totalidad del discurso en este espacio es científico y ocupa casi un tercio del total del discurso de la reunión. Además, en esta reunión el discurso científico se produce siguiendo un patrón discursivo concreto ya mencionado: en la GET de la figura 12, la franja entre el 40% y el 70% del discurso emitido presenta un patrón de oscilación entre discurso de contenido científico (CC) y didáctico de actividad (CD Act). Además de regular, este patrón discursivo resulta excepcional en cuanto a que el patrón esperable, que además encontramos a lo largo del

resto de las reuniones, ocurre entre el espacio científico-temático y el discurso CD Cont: se habla de ciencia, o de temas científico-tecnológicos, al discutir los contenidos. Uno esperaría, de hecho, que al discutir sobre qué actividades, cómo organizarlas, etc. (CD Act) también se hablara de los contenidos (CD Cont) y las metodologías (CD Met) y por tanto que el discurso ocurriera primordialmente en el espacio didáctico. En este sentido, resulta interesante preguntarse por qué en la reunión 4, en la que hemos visto que se sigue discutiendo sobre los contenidos a incluir, se habla tanto de ciencia. Y por qué se habla de ciencia mientras se está hablando de las actividades a diseñar.

Esta singularidad en el discurso de la reunión 4 coincide con un segmento de actividad concreto: «Presentación y discusión de actividades experimentales» (Figura 1). Es decir, el patrón de discurso identificado media una actividad de discusión de experiencias de laboratorio. Aunque podríamos asociar la actividad de diseño experimental con la presencia de discurso científico, esta característica por sí sola no explicaría por qué al discutir desde el plano didáctico las prácticas de laboratorio (cómo se realizan, cómo plantear la actividad, etc.) se habla tanto de ciencia. Esto puede atribuirse, de nuevo, a la diversidad de disciplinas de origen de los docentes del grupo. Como evidencian las citas a continuación, al describir experiencias propias de una disciplina (en el ejemplo, de física y química sobre transferencias energéticas) los docentes sin formación en este campo preguntan abiertamente sobre la ciencia implicada. El contexto interdisciplinar permite que los docentes se muestren como no expertos en la materia y favorece un cuestionamiento de gran valor tanto para unos como para otros.

Pep: a ver, cogéis un alambre ni muy delgado ni muy grueso […] y hacéis así (hace el gesto de doblar el alambre)… ¡¡y te quemas los dedos!! ¡¡Te quemas los dedos!!
Joan: pero el calor, perdona, ¿se genera donde estas doblando?
Pep: en la deformación, correcto.
Joan: no se genera en el lugar en el que te quemas […] quiero decir, que no es porque tú rozas el alambre con la mano.
Pep: no, no.
[…]
Roger: lo que pasa es, y el rozamiento ¿por qué daría calor?
Susanna: y el rozamiento ¿por qué daría calor?
Roger: sí porque yo no lo entiendo, tampoco.

Sin embargo, que los profesores hablen en el espacio científico no implica que lo hagan de forma científicamente correcta. Si el objetivo es explícitamente el desarrollo y aprendizaje docente en esta área, parece crucial el papel del experto en el ámbito.

Susanna: el rozamiento ¿por qué da calor?… a ver, ¡es que es un rozamiento! (ríe).
Pep: rompes enlaces.
Joan: hombre, ¡no rompes enlaces!
Susanna: no rompes enlaces… no, aquí en todo caso mueves el poco aire que hay.
Roger: ¿en la estructura?
Susanna: no, yo diría que el aire que hay entre una mano y la otra.
Joan: sí pero ¿en el vacío no tendrías calor?
Susanna: pues mira… ahora me lo tendría que pensar.
Pep: ¡¡es que hacéis unas preguntas!!
(risas)
Susanna: pero está muy bien, ¡está muy bien!

En todo caso, es interesante destacar que para que se produzcan este tipo de discusiones el grupo de docentes debe haber llegado a un cierto nivel de colegialidad y confianza mutua que no puede suponerse *a priori*. Se necesita superar el nivel de «pseudo-comunidad» (Grossman, Wineburg y Woolworth, 2000) para poder mostrar abiertamente la opinión y el conocimiento o desconocimiento propios, así como gestionar el desacuerdo y reconocer el valor de la incertidumbre. Aunque esta situación parece natural en el grupo estudiado, autoconstituido y autogestionado, se menciona en la literatura como altamente problemática.

Siguiendo con el análisis de las situaciones discursivas con mayor potencial de desarrollo docente, identificamos en la distribución del discurso didáctico la contribución del discurso didáctico metodológico (CD Met), que aun siendo pequeña en ambas reuniones (de un 7% y un 5%, respectivamente), resulta inquietante. Cabria esperar que el discurso sobre la metodología a seguir fuera puntual e inserido en SA en los que se discuten las actividades didácticas concretas, en medio de discurso CD Act. Aquí, sin embargo, en la reunión 2 el discurso metodológico está concentrado en una única secuencia discursiva larga y asociada a un SA de tipo «Demandar o aportar conocimiento declarativo» (Figura 1). En este sentido, el papel de este discurso en esta reunión no es el de acompañar el diseño de actividades didácticas, sino que parece tener un interés formativo. En los datos cualitativos vemos que en esta SD el coordinador, Roger, experto en técnicas de trabajo cooperativo, comparte con el grupo su conocimiento al respecto para que lo puedan incorporar en el diseño de materiales que están realizando.

Roger: yo proponía hacer, bueno, un trabajo cooperativo, ¿no? Utilizando la técnica del Jigsaw […] de los expertos […] ahora explico qué es, bueno, explico o … he traído aquí detrás esto del Jigsaw (señala un texto escrito por él y continúa con la explicación detallada de la técnica).

CONCLUSIONES DEL ESTUDIO E IMPLICACIONES DIDÁCTICAS Y METODOLÓGICAS

A partir del análisis cualitativo del contenido realizado, hemos caracterizado el discurso cooperativo docente en situaciones de innovación didáctica, determinando que tiene significado en tres espacios semióticos o bien que se produce desde tres planos de conocimiento distintos: el didáctico, el científico-temático y el espacio de acción sobre la cooperación. Mientras los dos primeros son propios del discurso docente en general, el tercero es un discurso asociado a las situaciones de cooperación. También hemos identificado subcategorías de estos espacios/planos, es decir, tipos de secuencias discursivas, siendo las más relevantes las que hacen referencia al contenido, actividades y metodología de enseñanza en el espacio didáctico; la ciencia en el espacio científico-temático y

la gestión y reflexión sobre el propio trabajo cooperativo en el espacio de acción cooperativa. Estos resultados responden a nuestra primera cuestión de investigación sobre cuáles son las áreas de contenido del discurso cooperativo docente.

Con respecto a la segunda pregunta de investigación, sobre qué nos dice el discurso cooperativo respecto de la propia cooperación y su potencial en el desarrollo docente, se han encontrado diversos resultados. En primer lugar, a partir de un análisis de la presencia y distribución de los diferentes tipos de discurso, hemos identificado *patrones discursivos* que indican ciertas características del trabajo cooperativo docente realizado. Así, se ha relacionado el patrón de presencia de discurso metacognitivo a lo largo de la reunión con la idea de «reflexión en la práctica» (de diseño cooperativo), necesaria no sólo por su incidencia en la calidad de la cooperación, sino porque permite desarrollar a los profesores la competencia de trabajar cooperativamente. También se han identificado *patrones comunes* asociados a actividades propias de los grupos cooperativos de diseño de unidades didácticas. Así, la actividad de selección de contenidos se ha identificado con un patrón regular y vertebrador de discurso didáctico del contenido con pequeñas incursiones en el espacio científico (o temático, si el enfoque es contextualizado). El diseño de actividades se ha identificado con discurso entre diferentes categorías (de actividad, contenido, metodología) dentro del espacio didáctico. Es decir, a partir del análisis realizado se ha encontrado una correspondencia entre ciertos patrones discursivos y segmentos de actividad, lo que puede ser de gran utilidad metodológica futura: a partir del análisis de los patrones de un cierto discurso, se podrán caracterizar y comparar las actividades principales del grupo, la tipología de cooperación, etc.

Como se ha visto en la discusión de resultados, los cambios en los patrones discursivos dominantes y la comparación entre los patrones existentes con los patrones esperados (como el caso del patrón de alternancia entre discurso didáctico del contenido y discurso científico vinculado a la discusión sobre actividades experimentales) han servido para identificar situaciones interesantes desde el punto de vista del aprendizaje y desarrollo docente. Consideramos que el interés de este estudio es ser una primera exploración de situaciones discursivas que, a priori, tienen potencial de desarrollo y aprendizaje docente, por ejemplo con respecto a la competencia de trabajo cooperativo o con respecto al conocimiento profesional de ciencia.

La presencia de estos patrones de discurso con potencial para el desarrollo docente no parece inherente a cualquier situación de cooperación sino dependiente de las particularidades del contexto cooperativo en el que se produce. En el caso estudiado, por ejemplo, podemos asociar el grupo *Scientia Omnibus* a una «comunidad de aprendices» en la que los profesores preguntan o muestran duda abiertamente, lo cual no es un caso típico. Como hemos visto, esta situación está favorecida por la interdisciplinariedad característica del grupo y de la innovación didáctica que diseñan, lo que sugiere la promoción de entornos interdisciplinares como contextos privilegiados que posibilitan el desarrollo y aprendizaje profesional. Sin embargo, también ha de tenerse en cuenta que, si bien estos contextos parecen favorecerlo, no garantizan que este desarrollo y aprendizaje se produzca o sea el adecuado, por lo que parece crucial el papel de facilitadores o expertos para gestionar el conocimiento a aprender.

La influencia de otras características del grupo estudiado, como liderazgo compartido, voluntariedad, autogestión, etc. que se vinculan teóricamente a la capacidad de formar comunidad del mismo, no ha sido estudiada aquí. Tampoco ha sido tenido en cuenta, al tratar el grupo de docentes como una unidad, la influencia de las características personales de sus participantes (expertitud, reflectividad, etc.). En este sentido, esta investigación deja interrogantes abiertos sobre todo respecto a la dimensión individual: ¿cómo se desarrollan los diferentes docentes en esta iniciativa? ¿cuál es el rol del coordinador? o ¿qué características de su discurso tienen mayor influencia en el desarrollo de la cooperación?

Del estudio discursivo de la cooperación docente realizado hemos obtenido también conclusiones metodológicas, en particular respecto de la combinación y adaptación de instrumentos de análisis discursivo y del contenido que se ha realizado. Consideramos que tanto los histogramas como las GET utilizados nos son útiles porque nos permiten obtener informaciones descriptivas y de conjunto del contenido del discurso de cada reunión. Es decir, nos permiten ver «de un vistazo» qué tipos (según el contenido) de discurso son más relevantes (en presencia) y, especialmente, con qué patrones aparecen los mismos, sin adentrarnos en estos discursos. Esto es especialmente importante para el caso de los análisis de interacción, que tratan de datos muy extensos que son difíciles de comparar entre sí y compartir. Ésta es, a nuestro modo de ver, la potencia de estos instrumentos y lo que nos lleva a utilizarlos. Sin embargo, ésta es también la limitación de estos instrumentos, ya que si bien nos permiten elaborar un perfil con respecto al contenido de la reunión no nos permiten extrapolar directamente lo que se habló. Por tanto, son útiles para comparar los tipos y patrones de discurso esperados en un cierto contexto con los obtenidos e identificar así momentos del discurso que conviene revisitar y analizar. Pero como hemos realizado en este trabajo, deben combinarse estos instrumentos con otros más cualitativos (Segmentos de Actividad, transcripciones iniciales) a la hora de discutir los resultados.

Los análisis del contenido son comunes en la literatura en enseñanza de las ciencias. También empiezan a serlo los análisis del discurso que se fijan en la estructura del discurso en la interacción, como los patrones de pregunta, respuesta y evaluación identificados por Scott y Mortimer (2003). Esta investigación pretende ser un primer paso de este tipo de análisis en el ámbito del estudio del desarrollo del profesor. Aunque el análisis realizado no es generalizable, sí consideramos que existe cierta transferibilidad de estos resultados a entornos similares y que nos dan ideas sobre cómo estudiar y organizar la cooperación docente para aprovecharla como contexto privilegiado de desarrollo y aprendizaje.

NOTAS

1. El grupo se origina en 1999 vinculado a la asociación de profesores Rosa Sensat y persiste en la actualidad, aunque dos de sus miembros (presentes en la etapa a la que corresponde la investigación de este artículo) dejaron el grupo por motivos personales sustituidos por otros dos miembros. La primera autora del artículo continúa vinculada al grupo en calidad de participante hasta la actualidad.
2. Desde el marco de la semiótica social, la autora utiliza la gramática sistémico-funcional de Halliday para identificar procesos (verbos) en el análisis del discurso multimodal del aula, y define estos espacios semióticos como los aspectos de la realidad a los que da significado un determinado proceso.
3. Se mide el discurso en caracteres en lugar de en tiempo real de habla por comodidad así como por significatividad, debido a que la velocidad a la que se produce el discurso en la reunión no es homogénea ni entre hablantes ni en los diferentes momentos de la reunión.
4. El eje horizontal, al graficar cantidad de discurso emitido, da una idea de dimensión temporal aunque no representa el tiempo real de duración de la reunión. Así, la indicación del 60% del eje horizontal no representa que ha transcurrido el 60% del tiempo de la reunión, sino que se ha emitido el 60% del total de discurso emitido en la reunión (medido en caracteres transcritos).
5. La unidad que realizan trata sobre energía exosomática (la energía que consumimos las personas que no es necesaria para nuestra supervivencia) y energía endosomática (la que consumimos para vivir), combinando contenidos de física, química y biología.

REFERENCIAS BIBLIOGRÁFICAS

ANGULO, F. (2002). *Aprender a enseñar ciencias: Análisis de una propuesta para la formación inicial del profesorado de secundaria basada en la metacognición*. Tesis doctoral, Universitat Autònoma de Barcelona.

BALL, D. L. y COHEN, D. K. (1999). Developing practice, developing practitioners. *Teaching as the learning profession. Handbook of policy and practice*. L. Darling-Hammond y G. Sykes. San Fransisco: Jossey-Bass. pp. 3-32.

BARAB, S. y DUFFY, T. (2000). From practice fields to community of practice. *Theoretical foundations of learning environments*. D. H. Jonassen y S. M. Land. Mawhaw, London: Lawrence Erlbaum. pp. 25-56.

BELL, B. y GILBERT, J. (1994). *Teacher development as professional, personal, and social development. Teaching and Teacher Education,* 10(5), pp. 483-497.

BELL, B. y GILBERT, J. (1996). *Teacher development a model from science education*. London: Falmer Press.

BLACK, P. y ATKIN, J. M. (1996). *Changing the subject. Innovations in science. Mathematics and technology education*. London: Routledge.

BRANSFORD, J. D., BROWN, A. L. y COCKING, R. R., Eds. (2000). *How people learn. Brain, mind, experience and school*. Washingtong, D.C: National Academy Press.

COCHRAN-SMITH, M. y LYTLE, S. (1999). Relationships of knowledge and practice: Teacher learning in communities. *Review of research in education*. A. Iran-Nejad y P. D. Pearson. Washington DC: American Educational Research Association. pp. 249-305.

COLL, C. (1998). *Observació i anàlisi de les pràctiques d'educació escolar.* Barcelona: UOC.

FENSHAM, P. J. (2004). *Defining an identity: The evolution of science education as a field of research*. Dordrecht: The Netherlands: Kluwer Academic Publishers (now Springer).

FULLAN, M. y HARGREAVES, A. (1992). *Teacher development and educational change*. London: Falmer.

GEE, J. P. (1999). *An introduction to discourse analysis. Theory and method*. London: Roudledge.

GILL, R. (2000). Discourse analysis. *Handbook of qualitative research methods for psychology and the social sciences*. J. T. E. Richardson. Leicester: BPS books.

GROSSMAN, P., WINEBURG, S. y WOOLWORTH, S. (2000). *What makes teacher community different from a gathering of teachers? Center for the Study of Teaching and Policy, University of Washington.* C.F.T.S.O.T.A. Policy: University of Washington.

GROSSMAN, P., WINEBURG, S. y WOOLWORTH, S. (2001). *Toward a theory of teacher community. Teachers College Record,* 103(6), pp. 942-1012.

HARGREAVES, D. (1999). *The knowledge creating school. British Journal of Educational Studies,* 47(2), pp. 122-144.

HOLSTI, O. R. (1969). *Content analysis for the social sciences and humanities*. Reading: Mass.

KRIPPENDORF, K. (2004). *Content analysis: An introduction to its methodology*. Thousand Oaks: Sage.

LEMKE, J. L. (1997). *Aprender a hablar ciencia. Lenguaje, aprendizaje y valores*. Barcelona: Paidós.

LIEBERMAN, A. y MILLER, L., Eds. (1991). *Staff development for education in the '90s : New demands, new realities, new perspectives*. New York and London: Teachers College Press.

LITTLE, J. W. (1993). *Teachers' professional development in a climate of educational reform. Educational Evaluation and Policy Analysis,* 15(2), pp. 129-151.

MÁRQUEZ, C. (2002). *La comunicació multimodal en l'ensenyament del cicle de aigua*. Tesis doctoral, Universitat Autònoma de Barcelona.

MELLADO, V. (1996). *Concepciones y prácticas de aula de profesores de ciencias, en formación inicial de primaria y secundaria. Enseñanza de las Ciencias,* 14(3), pp. 289-302.

MORTIMER, E. y SCOTT, P. (2003). *Meaning making in secondary science classrooms*. Philadelphia: Open University Press.

OGBORN, J. (2002). *Ownership and transformation: Teachers using curriculum innovations*. *Physics Education,* 37(2), pp. 142-146.

PERRENOUD, P. (1995). *Dix non dits ou la face cachée du métier d'enseignant*. *Recherche et Formation,* pp. 107-124.

PINTÓ, R. (2005). *Introducing curriculum innovations in science: Identifying teachers' transformations and the design of related teacher education*. *Science Education,* 89(1), pp. 1-12.

RODRÍGUEZ-BARREIRO, L. M. y ESCUDERO, T. (2000). *Interacción entre iguales y aprendizaje de conceptos científicos Enseñanza de las Ciencias,* 18(2), pp. 255-274.

RODRÍGUEZ BARREIRO, L. M. y ESCUDERO ESCORZA, T. (2000). *Interacción entre iguales y aprendizaje de conceptos científicos Enseñanza de las Ciencias,* 18(2), pp. 255-274.

SCHON, D. A. (1983). *The reflective practitioner: How professionals think in action*. New York: Basic Books.

STODOLSKY, S. (1991). *La importancia del contenido en la enseñanza. Actividades en las clases de matemáticas y ciencias sociales*. Barcelona: Paidós-M.E.C.

STOLL, L., BOLAM, R., MCMAHON, A., WALLACE, M. y THOMAS, S. (2006). *Professional learning communities: A review of the literature Journal of Educational Change,*(7), pp. 221-258.

TERHART, E. (1999). Developing a professional culture. *Changing schools,/changing practices: Perspectives on educational reform and teacher professionalism*. M. Lang, J. Olson, H. Hansen y W. Bünder. Louvain: Garant Publishers. pp. 27-39.

VALCÁRCEL, M. V. y SÁNCHEZ, G. (2000). La formación del profesorado en ejercicio. *Didáctica de las ciencias experimentales*. F. J. Perales y P. Cañal. Alcoy: Marfil. pp. 557-581.

WERTSCH, J. (1993). *Voces de la mente*. *Un enfoque sociocultural para el estudio de la acción mediada*. Madrid: Visor.

WESTHEIMER, J. (1998). *Among school teachers: Community, autonomy, and ideology in teachers' work*. New York.: Teachers College Press.

WILSON, S. M. y BERNE, J. (1999). Teacher learning and the acquisition of professional knowledge: An examination of research on contemporary professional development. *Review of research in education*. A. Iran-Nejad y P. D. Pearson. Washington DC: American Educational Research Association. pp. 173-209.

Content Analysis of Science Teachers' Cooperative Discourse in Contexts of Educational Innovation

Couso, Digna y Pintó, Roser
Departament de Didàctica de les Matemàtiques i les Ciències Experimentals, Universitat Autònoma de Barcelona

digna.couso@uab.es
roser.pinto@uab.es

Abstract

New reform contexts increasingly demand that teachers to be the leading actors of innovation, thus challenging teachers' learning and professional development. As a result, from a socio-cultural standpoint that relates social interaction with learning, teachers' cooperative work becomes a focus of interest. However, we know little about how science teachers work cooperatively for curriculum innovation, and particularly, how they develop professionally in these contexts.

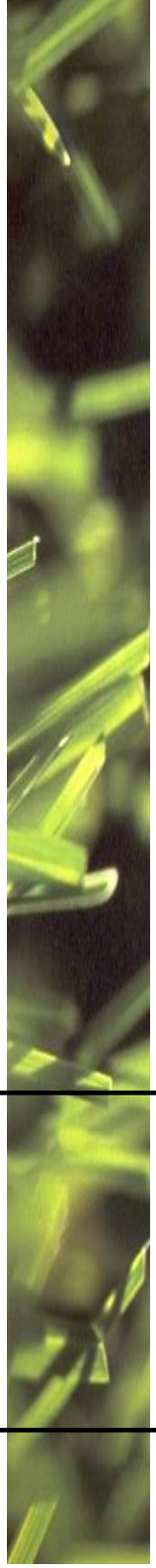
The aim of his research is to increase our knowledge in this field by doing a qualitative content analysis of teachers' discourse in cooperative scenarios. We analyse the discourse produced by a self-organised group of secondary-school science teachers when participating in curriculum design. The goal is to find the different distributions of teachers' discourse when involved in different activities of cooperative curriculum design, and explore the potential for teacher learning and development of these discourse distributions / activities.

To have an idea of the activities in which teachers are involved, teachers' meetings have been summarised and structured in *Activity Segments*. For the exploratory analysis of teachers' discourse, the types of discourse teachers use in these scenarios have been categorised in *Semiotic Spaces* and *Discursive Sequences*. *Semiotic Spaces* have been defined as the content-areas in which teachers' discourse has meaning. In our research study, three different *Semiotic Spaces* have been identified: *Didactical,* i.e. teachers' discourse about features of teaching, such as selection of content, teaching methodology, etc; *Scientific,* i.e. teachers' discourse within the science field; and *Cooperative*, i.e. teachers' discourse that acts upon cooperation, such as its management or regulation. While the first two are inherent to science teachers' discourse, the last one is context-dependent and characterises teachers' cooperation. *Discursive Sequences*, our analysis unit, are sequences of teachers' discourse that form meaningful units and refer to different features of reality within the same *Semiotic Space*. For instance, the selection of content and the classroom methodology belong to the same Didactical Space but refer to different features of it.

Apart from the qualitative identification of the content categories of teachers' discourse, a quantitative analysis of this data has been done. We have used two analytic and representational tools that are able to show the distribution *of* teachers' discourse for each meeting. *Histograms* show the total amount of a particular Discursive Sequence in a meeting, allowing easy comparison between general features of discourse in different types of cooperative meetings. *Thematic Clustering Graphs (TCG)*, a tool adapted from the discourse analysis field, show the chronological evolution of teachers' discourse, providing information about *when* (in which type of Activity Segment) teachers speak about *what* (the particular Discursive Sequences of their speech).

The results of this analysis show interesting discursive patters in the cooperative work of teachers. For instance, both the histograms and the TCG of the two meetings analysed identified the often and regular presence of metacognitive discourse throughout the teachers' meetings. This pattern can be related to the well-known Schön's «reflection-on-practice», not as regard the practice of teaching but rather the practice of cooperative curriculum design within the studied teacher group. In this sense, from the discourse analysis done, the group is characterised as a reflective one. A second interesting discursive pattern identified is the difference in the presence and distribution of discourse in the scientific field throughout the different activities. In particular, when teachers are deciding what practical work they would include in their teaching unit, the presence of scientific discourse increases in a significant way when compared with other design situations. When going back to the qualitative data of teachers' discourse that correspond to these patterns, we see that in these discursive situations teachers' make explicit their scientific understandings and also their doubts regarding subject matter knowledge. This interesting discursive exchange on subject matter seems to also be related to the interdisciplinary character of the teachers' group and the materials they designed. This has implications regarding the consideration of the cooperative context analysed as a fruitful professional development scenario for teachers.

According to these results, this exploratory study of teachers' cooperative discourse offers a first description of the discourse teachers use within a curriculum design setting. It also shows how the analysis of this discourse, in particular its distribution and discourse patterns, can be a useful tool for characterising teachers' cooperative work and identifying interesting professional development contexts.



SECTION 3.

Results and Conclusions

Discussion of Results

Conclusions and Implications

Discussion of Results

The research work presented here has examined the relationship between educational innovation and professional development in science education both theoretically and empirically. The review and analysis of the literature done in the theoretical framework have been used to propose a *new* model for science education professional development linked with science education reform. From the empirical research done in Publications 1, 2 and 3, aspects of this model are modified by and reinforced with empirical evidence. In this section of the work we summarise these results, including:

- Results of the theoretical, or literature analysis
- Results of the empirical analysis of Publications 1, 2 and 3

8. Results of the Theoretical Analysis

The interest in the field of professional development within contexts of educational innovation arises from a problem of fit between challenging aims of school-based/ teacher-centred reform and traditional designs of professional development that do not adequately support teachers to face them. The literature analysis done in this research explores this reality and proposes a *new* conception of professional development in contexts of educational innovation, based on different principles. In the following we summarise these principles.

Regarding the process of professional development

Professional development is viewed as a self-development process of the teacher that can be externally supported with the use of intentional professional development activities, within an also intentional professional development scenario of science education innovation. Professional development should be an ongoing, job-embedded process for the teacher. Professional development should be systemic, addressing not only the teacher but also school-development within the wider socio-political context.

Regarding the scenarios that support the professional development of teachers

The scenarios that support the professional development of teachers in contexts of educational innovation are characterised by a focus on the subject; authentic cooperation, and an inquiry/reflective stance, with teachers sharing the common goal of fostering students' learning by becoming professional learners themselves. According to a situative and socio-constructivist view of teacher learning, this means that what teachers already know and do have to be taken into account; that learning occurs within the professional activity and that learning needs interaction with others, both teachers and researchers. Each of these tenets has implications for a *new* professional development model, which are summarised in the following:

- Within a constructivist view of learning, teachers develop and learn within their ZPD (Zone of Proximal Development) and schools develop and change within their ZFD (Zone of Feasible Development). Attempts addressed to both teachers and schools development need to take into account existing knowledge, beliefs, attitudes and practices, and address change as evolution of those instead of radical replacements. This implies that in the new view of

professional development there can not be imposition of technical ideals but a support for self-development.

- Within a situative perspective of learning, learning is situated in practice. According to the new view of professional development, the practice of teachers is extended and crosses the borders of the classroom, the staff room and even the school walls. In this sense, teachers' professional activity, and thus learning and development, occurs across these multiple scenarios. While becoming reflective practitioners, curriculum designers or practitioner researchers, among others, teachers learn part of the knowledge they need to play these new roles. Teachers also need other sources of knowledge.

- The knowledge teachers need for developing professionally is both formal and practical knowledge, *for* practice and embedded *in* practice. For teachers to learn the formal knowledge-based, socio-constructivist research-based teacher education activities need to be planned. For teachers to be able to deconstruct the tacit knowledge embedded in their or other expert teachers' practice, reflection on practice should be fostered. However, with these two sorts of knowledge the teacher does not have enough. Teachers should also position themselves in a new relationship to knowledge, so that part of the knowledge they use comes from their own research and inquiry of practice.

- Within the new view of professional development, professional development scenarios are related with new school cultures in which teaching practice is opened to scrutiny and critical interrogation. These are referred to as reflective, inquiring, problem-solving or practitioner research cultures. All them imply not only a new relationship to knowledge, but new goals, discourses, practices, rules and views of the profession, that is, new roles of teachers that go beyond teaching. In these cultures, *evidence* (what constitutes educational evidence, how to gather evidence and how to analyse it for understanding and changing practice) acquires a new importance in the teaching profession.

- Regarding cooperation, this strategy acquires a crucial dimension within this *new* model of professional development intertwined with school-based innovation within a socio-constructivist perspective. Collegiality is a necessary but insufficient condition for school-based reform. Collaboration,

despite essential for teacher learning, does not imply a change in the culture. It is necessary *authentic* collaboration within a community of practice in which there is sharing of beliefs, values and understandings, interdependence, concern for individual and minority views and meaningful relationships in addition to interaction and participation. Despite collaboration is needed and enhances the learning potential of any individual strategy (reflection, inquiry and any other cognitive activity the teacher does), it is within a community that these strategies can become part of the culture (a culture of reflection, inquiry or research), and thus attain some sustainability.

- The focus of these reflective and inquiry school cultures is the improvement of students' learning. This is the shared community goal, the explicit collective enterprise that gives meaning to the formation of community. However, in a *new* view of professional development it is emphasised and explicitly stated that students' learning will not improved if not made problematic, and as any open problem, tried to be solved. This poses teachers, researchers and teacher educators as learners in the profession, ready and open to search for solutions adapted to the new problems and contexts of each school. All agents involved in educational change should envision themselves as life-long learners in the profession. In this sense, the *new* view of professional development proposed relies on notions such as Professional Learning Communities, in which all participants learning is fostered towards the common goal of increasing students learning.

- The model stresses also the importance of a focus on the subject for different reasons. Empirically, professional development initiatives that have focused on the subject, in particular in how learners learn the subject, have shown to have better results in terms of teachers' perceptions of professional development but also real change of classroom practice. In addition, the subject is the centre of teachers' socialization and, as thus, views of the subject culture can interfere with the *new* cultures that want to be promoted. It is also the case that epistemological views of both science and school science influence teachers' didactical models and classroom practice, and thus, they have to be taken into account. Finally, the new reforms and innovation trends in science education within frameworks such as *Science for all, STS, Public Understanding of Science,* etc. challenge traditional views of

the subject and demand a re-invigoration of the curriculum that also challenges teachers' knowledge, beliefs and attitudes.

- A great diversity of designs can aid the professional development of teachers in different ways. Different families of designs are proposed, including Vehicles and mechanisms, such as traditional workshops and seminars; Practicing teaching by co-teaching and mentoring; Aligning and Implementing curriculum; Collaborative structures such as study groups and school-university partnerships; Examining teaching by inquiry and action research and Immersion experiences in the way learners learn the subject. Other ways of categorising professional development designs are also possible. The importance of this diversity of designs is the fact that all contribute to the professional development of teachers, but in different ways according to the aforementioned types of knowledge and learning. Some address the learning of knowledge for practice in a mainly additive learning fashion. Others are useful for the learning of knowledge *in* practice, both with additive and transformational intentions. Finally, some deal with knowledge *about* practice, being strategies useful within the reflective, inquiring or researching learning communities that want to be fostered in the school, in which learning have the bigger possibilities to provide evolution of conceptions and change of practice. As such, these are for us central strategies. All the others, however, are also needed: they can be combined within a design of professional development and deal with the different kinds of knowledge needed in something as complex as being a teacher.

The results just mentioned picture a theoretical model for science teachers' professional development within contexts of school-based and teacher-lead educational innovation. We have tried to represent the complexity of this model in graphical form (See Figure 7). As can be seen, the growing grey arrow in the middle of the picture represents the process of professional development within the aforementioned context of school-based and teacher-lead educational innovation. The evolution in the horizontal axis represent that this process is ongoing. By being in the middle of the vertical axis, this process is systemic in the sense of being school-based, at the level of school and teachers' community.

Figure 8 adds the characteristics of the professional development scenarios to the picture, in the form of three columns. Reading from right to left, the first column refers

to the level the professional development activities or scenarios are addressing. In this sense, it conveys the same meaning than the vertical axis representing the systemic orientation. In the middle column it is represented the approach that it is proposed in this model for professional development activities and scenarios. Finally, the left-hand vertical column lists examples of professional development designs.

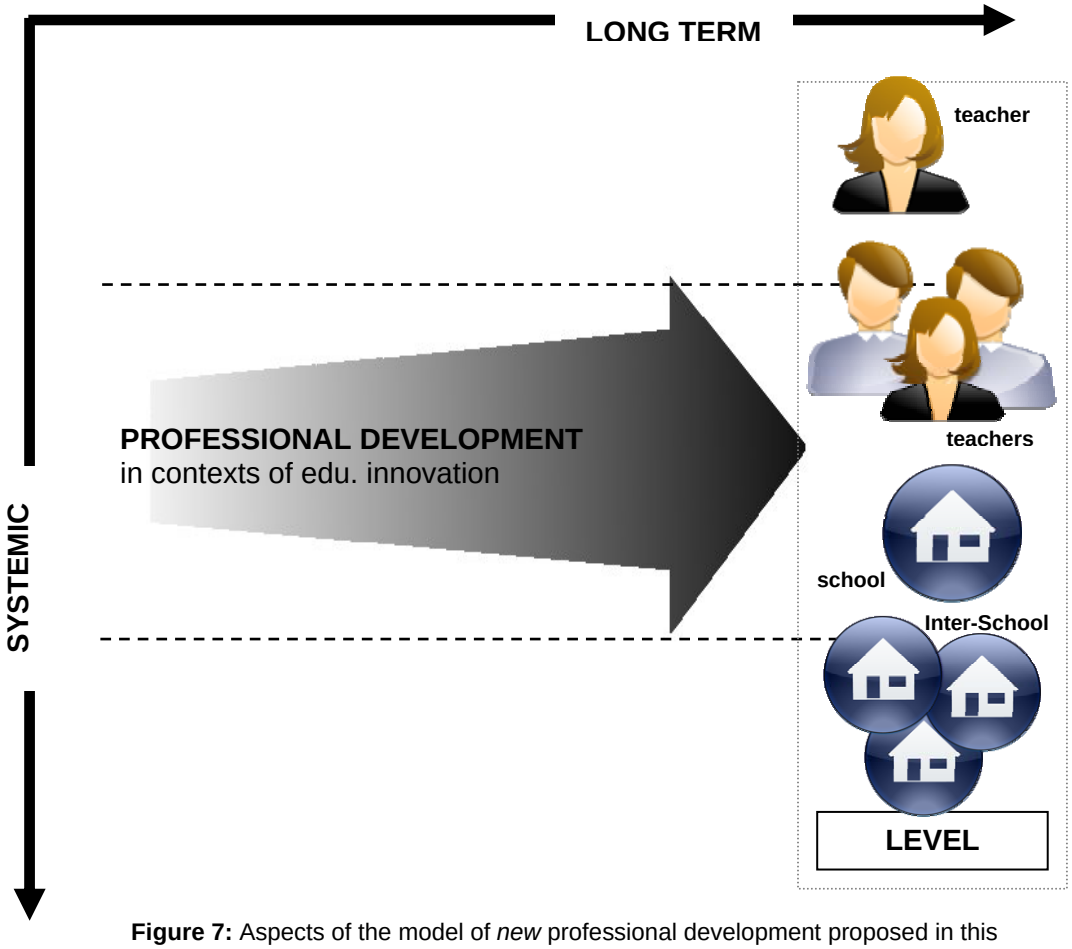


Figure 7: Aspects of the model of *new* professional development proposed in this thesis. It is represented a model of professional development which is ongoing and systemic at the teachers' community/ school level.

The right-hand column represents the different levels professional development activities and designs can address, from the individual teacher, group of teacher, the school, inter-school systems and the wider socio-political level.

In the left-hand column, a list of examples of professional development activities (addressing the teacher) or scenarios (addressing the schools or community of teachers) is shown. This list does not try to be exhaustive, but just show that broad sources of professional development designs are available, being the task of the

teacher leader, teacher educator or researcher to choose the most appropriate one at each time of the professional development process, according to the goals pursued. The arrows that flow from these activities to the process wants to represent how this diversity of activities, even those addressing the individual level or doing in networks of schools, contribute to the professional development process.

Independently of what design or combinations of designs are used for professional development, within our model all professional development activities and scenarios should follow the same approach. This is shown in the middle column. The triangles try to represent this aforementioned common approach of professional development with a focus on the subject, a collaboration model of participation and a reflective stance. This approach can be enacted in practice with different forms, regarding the level to be achieved. If a professional development activity addresses the individual teacher level, this activity should focus in the subject and in reflection on practice, doing so in a collaborative manner (with other participants in the seminar, workshop or course). However, when teacher community or school professional development is aimed at (or when we address teacher development at the school level, for an extended view of the teacher), this same concepts vary their meaning slightly. There continues to be a focus in the subject, which quite often becomes a focus on the curriculum being implemented. The dimension of reflection refers here to the reflective or inquiry, problem-solving culture in the school or teacher community level. Accordingly, collaboration refers here to the community building necessary for this culture to “take root”.

In this sense, Figure 8 tries to represent some of the most important aspects of the theoretically proposed model for professional development. However, some interesting ideas regarding learning can not be included here, due to the graphic complexity the representation would achieve. Figure 9 tries to represent these missing aspects related to the situative and socio-constructivist view of learning hold in the model, and the views of knowledge used, both represented at the teacher and the school/teacher community level.

In Figure 9, the process of professional development is represented in the same way as before (grey growing arrow) as an ongoing and systemic process. We focus now on the teacher (individual) level and the community/school level. When considering teachers’ individual learning for professional development, this occurs within the Zone of Proximal Development of the teacher and aims to produce teacher didactical

change. Notions of constructivism apply, taking into account both what the teachers know and how to promote conceptual change and evolution of his/her views. On the contrary, when teacher learning is addressed as the community or school level, the notion to take into account is that of Zone of Feasible Development of particular teachers in particular contexts. In this sense, cognitive, social and contextual factors all play a role. The learning to be done is different, within a socio-constructivist and situative approach. Here teachers learn while doing, by doing and by reflecting on doing with others, within a community that does more things than teaching and shares these common goals. In both cases of addressing individual and school/teacher community development, it is stressed the importance of external support for teachers to cover the zones of proximal/feasible development.

In Figure 9 it is also represented what is to be learn regarding the proposed model of professional development. Knowledge *for* and *in* practice are related to individual conceptions of learning. Despite they are better learnt, as all learning, in collaboration, they generally do not imply a learning that address the school level, that is, that addresses problems of the school defined within a community. Knowledge *about* practice, on the contrary, is the sort of knowledge that is generated within the school and community purposefully to address these problems. Again, this does not mean that the previous forms of knowledge are not interesting and helpful, but that the latter form is not to be neglected in a model of professional development in contexts of school-based educational innovation.

Figures 7, 8 and 9, then, represent a graphical summary of the different aspects of the theoretically based professional development model proposed in this research.

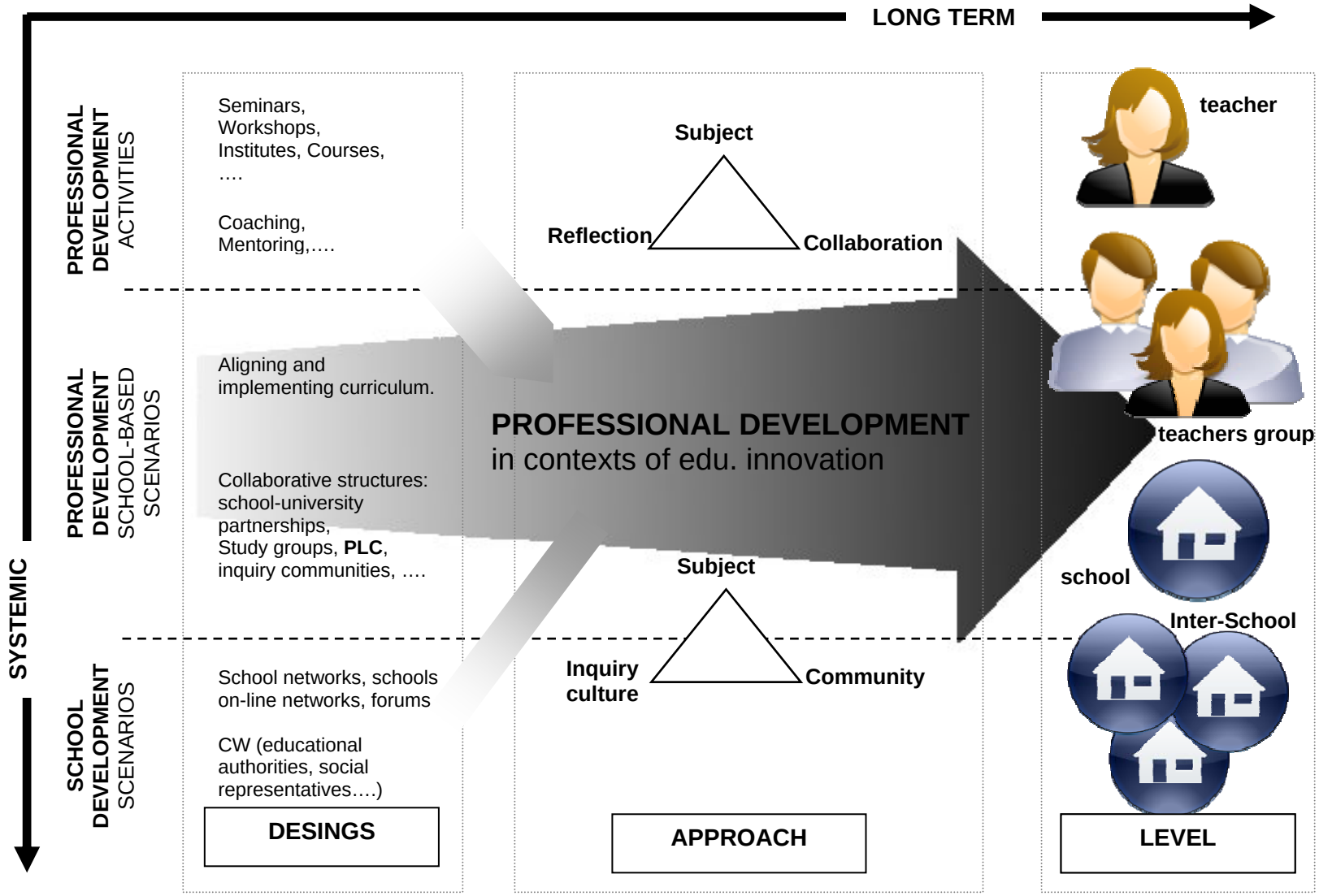


Figure 8: Aspects of the model of *new* professional development proposed in this thesis. It is focused in the subject, collaborative and reflective /inquiring at the teacher, group of teachers, school and school network level.

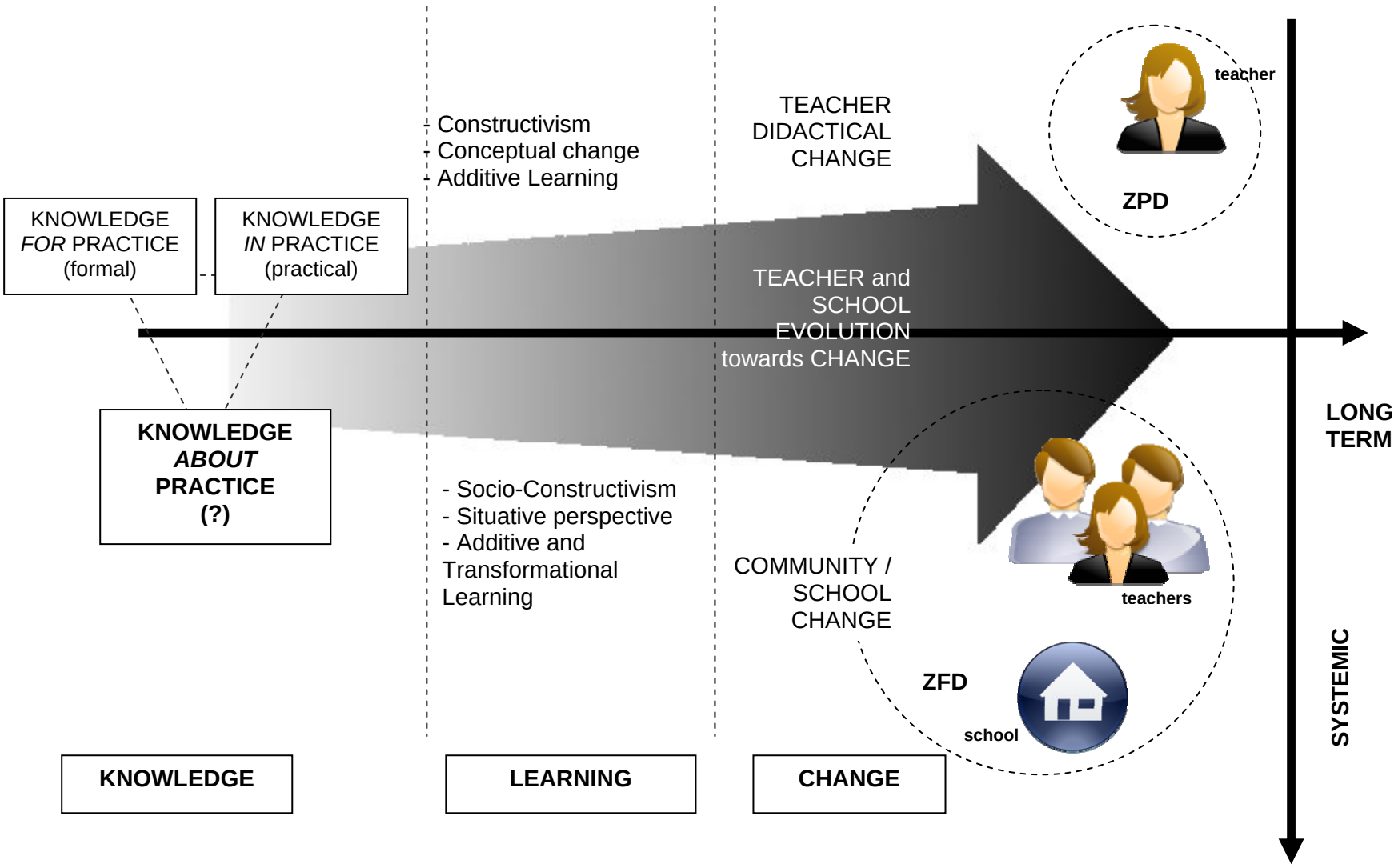


Figure 9: Aspects of the model of *new* professional development proposed in this thesis. A situative and socio-constructivist view of teacher learning and teacher and school change is represented, together with the different visions of knowledge discussed in the model.

9. Results of the Empirical Analysis

Publications 1, 2 and 3 have particular results that, as has been discussed before, are independent and coherent with each of these pieces of research purposes and contexts. However, some of the empirical results found can be seen as empirical additions to the theoretical model above described. In the following, we will briefly describe these contributions and situate them within the aforementioned model.

9. 1. Discussion of research results of Publication 1

Research results from Publication 1 show that some alternative conceptions of teachers regarding scientific concepts are very problematic. These conceptions show persistence and certain universality, and despite efforts from the teacher part to overcome them, this is not done in practice. The more problematic issue is the correspondence of these conceptions of teachers with the extensive literature on students' conceptions. In this sense, they need to be overcome. A complete model of professional development needs to have room for opportunities to deal with these research-identified conceptual problems.

In Publication 1 it is argued that one way to overcome these conceptions it is by confronting them in a teacher education programme with a socio-constructive and meta-cognitive approach, following a learning cycle. Despite Publication 1 does not offer empirical results regarding the effectiveness of this programme, its framework is theoretically justified. The teacher education workshop discussed in Publication 1 follows the approach of the model of professional development proposed in this research: it is focused on the subject and it addresses individual learning by using reflection and collaboration. However, this teacher education activity has characteristics that need to be added to our model. First, this teacher education scenario is research-based, drawn on extensive previous research in the field and also concrete research in the particular context in which the innovation wants to be implemented. Second, due to the extensive research, it is very clear what is the problem and what it is expected to be achieved, thus allowing the definition of concrete and explicit learning outcomes regarding teacher learning. Third, the approach takes into account what teachers' know and aims to change practice, which is the critique that traditional training activities similar to this one have received in the literature.

Despite we would not restrict that all professional learning activities addressed to the single teacher should be exactly like the one in Publication 1, we think that the mentioned characteristics should certainly apply. In the literature it is known that traditional training sessions or activities are the less effective scenarios for teacher professional development, and as such, they have to be designed very carefully to be able to have some impact. When difficult alternative conceptions want to be addressed, doing so in scenarios were much more is happening (for instance, while designing curriculum) and teachers have to have in mind not only content but also many other issues (how to present the activity, which context, how to assess it, etc) does not seem the best solution. A combination of both, where the conceptions are recognised as problematic in the training course and reconstructed along the curriculum development and teaching practice seems to be a better scenario. However, as it is shown in Publication 1, for the conceptions to start to be recognised the training activity needs to be detailed designed.

9. 2. Discussion of research results of Publication 2

Research results from Publication 2 show that there is an interesting approach for the professional development of teachers at the meta-level that was not included in our model because it is not common in the literature. According to the results of this research, teachers participating in a discourse guided and supported to be at the meta-level, that is to address the wider social and political contexts outside their schools, allow them to understand better their practice in school-based innovation, co-construct their identities and, as a result, show empowered. This is done using a particular design, the Curriculum Workshop, which shows to be an effective instrument for achieving these sorts of outcomes and constructing/raising the teachers' voice.

These results have important consequences regarding the proposed model. When professional development scenarios become more systemic, addressing purposefully and specifically the school networks and the socio-political context, teachers can benefit from an approach slightly different than the one previously presented. At this level, the focus on the subject continuous to apply, regarding the justification of the curriculum orientations in the wider scenario (what sort of subject do students need within their social contexts). However, at this level the inquiry culture of analysing classroom practice is transformed to an inquiry and reflection stance on the teaching

profession itself, at the meta-level. As a result, the community is spread, and in designs such as the CW proposed in Publication 2, other agents than teachers and researchers can be included, such as educational authorities or relevant community members. These professional development activities address wider, out-of-school educational audiences. For teachers, these scenarios can be an opportunity to raise their voice and build their identities, as the results of Publication 2 show. In this sense, it is important to include this sort of professional development activities even though they will not be the most frequent ones. In our model we introduce them considering that, despite reflection at this wider level will not be part of the everyday job of the teacher, it should also not be the case that this sort of wider reflective scenarios are something completely exceptional.

9. 3. Discussion of research results of Publication 3

Publication 3 offers results regarding a community of teachers' working cooperatively in the design of a curriculum innovation. In this sense, it is a scenario that resonates with the central professional development design proposed in our theoretically based model. Due to this reason, the results of Publication 3 directly address the main interest of this research and are the ones that can contribute more to enrich the proposed model.

The results of the discourse analysis done in Publication 3 show that, within these scenarios, a focus on content-knowledge that makes teachers discuss their conceptions and share their understandings does not happen easily. Even within a teacher group that has characteristics of a community of learners such as that of Publication 3, were teachers show to have shared interests, beliefs and values, and meaningful relationships in a climate of trust, teachers do not generally discuss about scientific content just because it is not necessary for them in the context of the activity they are participating in. This is one of the problems, regarding their professional development potential, of some community scenarios of curriculum innovation: they involve discussions mostly in the "didactical area", discussing the sort of activities or the context of the activities (in particular in curriculum innovations where a contextualised approach is pursued) without discussing explicitly or deeply about subject matter and pedagogical content knowledge. Despite a focus on didactical discourse is not problematic on its own, a curriculum design scenario where scientific content is never referred to can not be considered a complete professional

development scenario and will have shortcomings. In this sense, it is quite important the findings of Publication 3 in which certain curriculum design contexts and tasks, such as the exchange, discussion and design of laboratory activities, allow for discussion and exchange focused on subject matter to happen naturally. In this sense, the interesting empirical contribution of Publication 3 to our model of professional development in contexts of educational innovation comes from findings from a micro-analysis of teachers' discourse that help to identify macro-discursive patters that refer to interesting, regarding their potential impact in the professional development of teachers, discursive situations as the one mentioned.

According to the discussion of results of Publication 3, however, the discursive pattern on scientific content does not seem only related to the activity the teachers' are doing, but also to the particular social context, the community, in which the activity takes place. For some of the participating teachers, the idea of community directly apply, in the sense that these professionals know each other from quite a long time and there is an atmosphere of trustfulness and sharing. However, for other teachers and the researcher as participant observant, the group was new and these were their first series of meetings. However, even for these participants it was easy to enrol in the discourse on scientific content, showing explicitly doubt, erroneous conceptions, etc. From the results of Publication 3 this seems to be related with the fact that the group composition was interdisciplinary within science, in the sense that expert teachers in their field did not seem to find difficult to show lack of expertise in other areas, despite they were designing materials regarding this knowledge. This issue is quite important, as learning demands of teachers become explicit along their discourse. This could be a way of producing the necessary "levelness of the playing field", as mentioned in the theoretical framework. However, due to the fact that none of the teachers were or acted as expert in scientific knowledge, some of the problematic conceptions teachers' mentioned remained unresolved (at this stage). In this sense, there are lessons to be learned from results of Publication 3 that we need to include in the model of professional development we are elaborating in this thesis.

In the literature there was certain ambiguity regarding both teacher composition and the role of facilitators, either as teacher leaders or educational researchers, in the structure of school-based innovation scenarios such as professional learning communities. Regarding composition, due to the fact that these scenarios are ideally considered to be the normal working context for teachers, selection of members does not seem to apply. However, as we have seen, for particular aspects of curriculum

design and teacher learning certain compositions of teachers produce better results than the ones expected from other groupings. This is in coherence with the extensive literature regarding students' peer work, which emphasises the importance of heterogeous or homogenous organizations for particular tasks and learning outcomes. In this sense, we consider that composition of teacher communities, groups and collaborations should play a role. It would be interesting, for instance, that science teachers from different disciplines worked together regarding an interdisciplinary science curriculum; or that the group of teachers in charge of an study-group on problem-solving techniques develop their expertise with their colleagues from the math department, for instance. As a result, community needs to be explicitly explained as not referring to a static group with which to share and learnt always, but as a culture of teachers working and learning together within which the more appropriate collaborative setting for particular goals can be chosen.

The organisation of the aforementioned structure of collaboration raises the same questions as the possible lack of particular expertises within the school community. Despite supporting and guiding the work in the community is considered important, it is not clear in the literature if this role is played while establishing the community, while researchers are available or always. There have been some claims of the costs involved in school-based innovation if university or teacher education facilitators were always needed. In this sense, achieving sustainability is an issue. However, despite this is possible to be achieved regarding the formation of the community culture, ways of working, etc., certain expertise about particular topics would always be needed. The important notion here would be to teach teachers to regulate their learning process, so that they can identify themselves when knowledge is needed and expert guidance should be obtained. In the same sense that students' meta-cognition is promoted so that the student becomes an autonomous learner, teachers within these school-based innovation scenarios should also become autonomous learners which identify learning needs and seek for solutions, demanding expert help if necessary. This should be addressed by facilitators while supporting the formation of school communities. One important feature, then, would be to organise teacher cooperation with the aim of sustainability in their use of research results and professional guidance. Easier and cost-effective forms of research-based support, such as ready-to-use summaries of research results (for instance, the famous PICO letters of PING) or professional support in specialised on-line forums should also be made more available and introduced as essential for the work in educational innovation.

The above mentioned suggests, from research results, that school and teachers' community are more complex terms than they seem at first glance. It is not only difficult to promote the culture of mutual trust, meaningful relationships, shared values and beliefs etc. that the literature discusses as crucial so that real community is form … the main problem is for a group to become a *learning* community, and because learning does always takes place, an adequate learning community where the adequate professional knowledge is learnt. Despite community need to be guided up to a certain extend, the goal should be for the community to become an autonomous learning scenario.

The previously mentioned aspect connects with a different result from Publication 3, that of the existence of a meta-cognitive discourse in teachers' cooperative discourse when designing curriculum innovations. This discourse guides the group work of teachers in an interesting way. We think that this sort of discourse could be the source of the aforementioned desirable meta-cognitive discourse regarding teachers' learning. Within a community or teachers' that explicitly emphasise teachers' learning as one of their goals, the meta-cognitive discourse that manages the collaboration could also take care of what knowledge is needed and how it could be obtained. This should be, then, the main focus of teacher education for the preparation of teacher leaders, and also the focus of researchers playing the role of facilitators in teachers' groups: the establishment of a culture of professional cooperative learning where professional learning is recognised as necessary and thus the central goal when aiming to increase students' results. How to learn and what, by using research-based results and an evidence-based /inquiry /reflective approach, should be central points to be explicitly discussed. Groups such as the one of Publication 3 show that there is a seed for this to happen among reflective practitioners, but this sort of discourse needs to be institutionalised.

Figure 10 shows the model for professional development in contexts of educational innovation resulting from the aforementioned theoretically-based model of Figure 9, when including the empirical results and implications discussed from the analysis of Publications 1, 2, and 3. This results and implications have been added in red in Figure 10. In this sense, Figure 10 constitutes the final, theoretical and empirically-based model proposed in this research for professional development in contexts of science education innovation.

In this model of Figure 10 we have included the necessity of well-designed research-based teacher training on subject matter at the individual teacher level (See #1 in Figure 10); we have extended the “triangle” that describes our approach for professional development towards a meta-level of reflection at the socio-political context (See #2 in Figure 10) and we have made explicit the necessity to act upon the formation of community and teachers’ group, taking into account the planning on the group composition and the facilitation of support, to allow the achievement of sustainability of teacher learning (See #3, Figure 10).

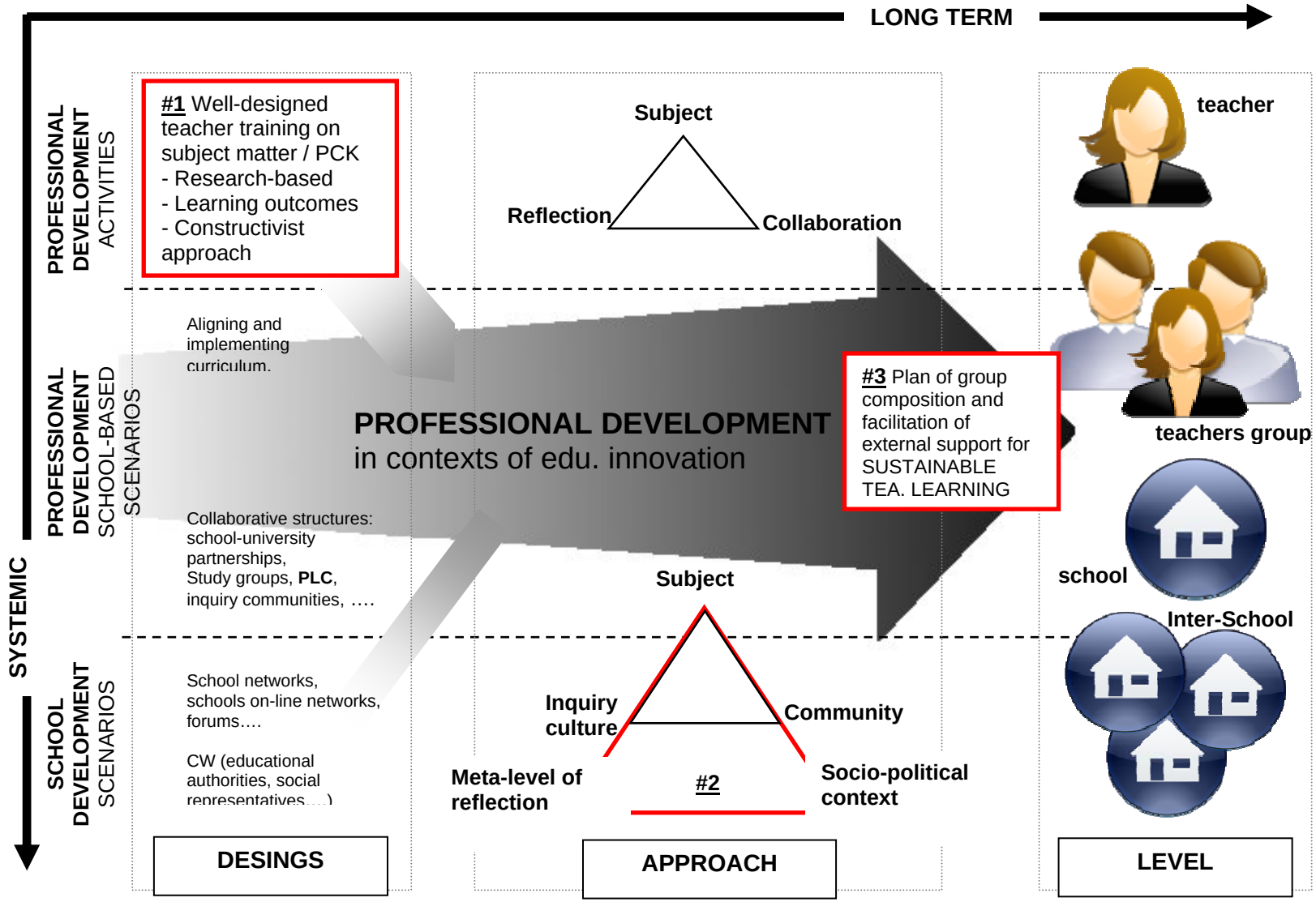


Figure 10: Aspects of the model of *new* professional development proposed in this thesis, including contributions from the empirical analysis (in red)

Conclusions and Implications

From the aforementioned global results of both the literature and empirical analysis, some conclusions are drawn regarding the professional development of science teachers in contexts of educational innovations, which have also certain implications for future research and design of professional development.

10. Summary, Conclusions and Implications

> "Our overarching conclusion is that teacher development must be conceptualized much more thoroughly than it has been. Its relationship to educational change is not just a matter of better implementation of selected innovations (although it includes this) but more basically a change in the profession of teaching, and in the institutions in which teachers are trained and in which they work. Teacher development is thus tantamount to transforming educational institutions. Fortunately this is becoming the agenda of the 1990's, although it is unlikely to receive the deep and continuous attention it requires." (p.6)
>
> M.Fullan and A.Hargreaves (1992)
> *Teacher development and Educational Change*

At the beginning of the 1990's Fullan and Hargreaves (1992) announced an agenda focused on teacher education for educational change. The extensive literature on Professional Development proves that, at least within the research field, the authors were not right. Professional development as a research field has received deep and continuous attention, and in spite of this, more research results and knowledge is needed. The research work done here has intended to account for part of this literature and have tried to contribute to this field with new results.

The purpose of this research was to examine the relationship between educational innovation and professional development in Science Education, arguing for the necessity of both scenarios to be intertwined when teachers are expected to play an active role in educational change. The aim was to provide a theoretical and empirically based model for the professional development of science teachers in contexts of innovation. As a result of a theoretical analysis and including some empirical findings from the three different pieces of research in the field included in this compendium, a model for a new view of how to promote the professional development process of teachers within scenarios of science education innovation has been proposed (See Figure 10).

The model of Figure 10, discussed in the previous section, answers the general research question that has driven this work:

- What can be a model for effective professional development of science teachers in contexts of educational innovation?

The models of Figure 9 and 10 answer also the particular research questions posed regarding the two different analyses, theoretical and empirical, that have been done:

- How does this model (for effective professional development of science teachers in contexts of educational innovation) relate with the extensive theoretical contributions and research results in the field?

- What empirical contributions to this model (for effective professional development of science teachers in contexts of educational innovation) can be made from the research results of three pieces of research (Publications 1, 2 and 3) that explore aspects of professional development in different contexts of innovation, from top-down, short-term and research-based teacher training proposals to bottom-up, on-going, collaborative and reflective curriculum and meta-curriculum development initiatives?

In this sense, as a result of this research work, it is offered a model for teacher professional development that includes a variety of designs for professional development activities which are used to feed the ongoing professional development process of teachers at the systemic level of the teacher community and the school. This professional development process is intertwined with science education innovation, following an approach that focuses on subject-matter from an inquiry/reflective stance in a collaborative way. The purpose is to increase students' learning by enrolling teachers in sustainable teacher learning scenarios, from a socio-constructivist and situative perspective on learning.

The above described model is a summary of the results from the theoretical analysis and pieces of research included in thesis. In this sense, the main conclusion we can derive from this research work is that it is possible, at least theoretically, to propose a consistent research-based model for teacher professional development that brings together knowledge and empirical results from both the teacher education and the science education reform fields, and which takes into account what we know about how

teachers' learn and how school cultures change. In this sense, such a model breaks the unidirectional link of professional development with teacher education to give an operational definition of professional development understood as bi-directionally linked with school-based innovation in science education. This operational definition is an attempt to guide how to organise professional development and science education reform, or in other words, science teachers' change and school change, for the maximum effectiveness and sustainability of both process. Despite different aspects of this model have been analysed in the reported or conducted pieces of research described along this research work, particular designs globally inspired in this model need to be done in the future, in order to analyse its real potential in different school settings.

The aforementioned is not the only conclusion of this research, despite being the main one. Each of the pieces of research included in this compendium of papers has its own research conclusions adequately reported in Publications 1, 2 and 3. These conclusions include not only the aspects of teacher professional development that we have taken into account in our model, but also some methodological implications of interest for those analysing teachers' conceptions, collaborative reflections and both micro and macro analysis of teachers' cooperative discourse. However, here we will not report again these particular conclusions, as they have only complete sense in the concrete context of the research undertaken. In this sense, here we have just included the general conclusion we have obtained from the effort to synthesise some results from these three different pieces of research with the theoretical framework we have been developing along the time of designing and analysing them, to be able to offer an overarching model that summarises the ongoing construction of our view of the professional development and science education reform field. In other words, the piece of research we have reported here in this thesis is also an account of what we have learnt and can conclude during this long process, through the three research projects undertaken.

The model for professional development in contexts of educational innovation we propose here have deep implications, as it both derives and implies a different view of the teaching profession than the one present in most teacher education and reform initiatives. We would like also to share with the reader our views regarding these implications, which are related to important concerns in the professional development field.

Our first concern regarding the professional development field is the fact that teaching remains largely unchanged while other professions have dramatically transformed. This has been remarked before, referring to the school, the classroom culture, the subject and, of course, teachers and teaching. We think that there is much more change going on than what is seen from a superficial look, the innovations analysed in the different pieces of research of this compendium being an example. There is still, however, a lot of work to do in the field for this image of the teacher as a changing professional to become widespread. For us, one of the problems is a distorted view of teachers' professionalism, which is present in society but also within the profession. There is not a wide recognition of the profession of teaching as having a concrete knowledge-base that needs to be mastered, even less that the evolving nature of its social context makes necessary the continuous learning and generation of new knowledge in the field. Any model of professional development that wants to address this issue needs to recognise explicitly the ongoing, research and evidence-based nature of this life-long learning process. Unfortunately, this is not generally the case. Recent public discussions regarding what should be the form for pre-service secondary school teacher education in our country, for instance, shows that a knowledge-base for science teaching is not globally recognised, and when it is, this knowledge-base is not directly related to research results in the field, and even less to inquiry and reflection on practice. The discussions around the form of this new teacher education do not refer to it as just the first step in the professional development of science teachers, which would imply to mostly teach the student teachers how to learn in a lifelong learning profession; they also not mention the need for a systemic approach, addressing important issues of school culture and emphasising the contact with schools; and finally, this teacher education is not linked with innovation and reform in science education. The model we propose here would be helpful, if not for organising the structure of this initial teacher education (which is done by educational authorities), at least to realise that some of the aspects mentioned should also be taken into account.

In our opinion, the most interesting issue behind the idea of linking science teachers' professional development and school-based science education innovation (the issue that motivated an interest in this field and thus, this research) is to have realised the fact that schools, despite their intention to be intellectually exciting places for students, are not generally so regarding teachers. For teachers to acquire and maintain a satisfactory level of intellectual stimulus with his or her profession they have to do a great effort, an *extra* effort, an everyday swim against the current. This is why some

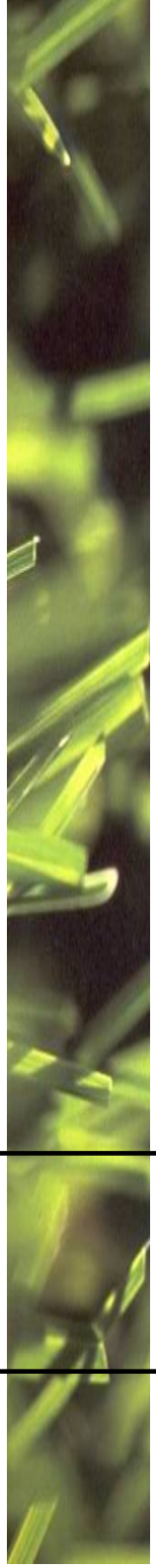
teachers come closer to the university looking for people with whom to share their concerns, their interests, and their theories. They are looking for a different culture than what the one they find in their schools. Would it not be better that they could find such a culture in their own schools, in their workplace? By understanding school-based reform as the only reform possible to have success and by arguing the need to intertwine this with the process of professional development of teachers, the intention of this work is to claim for a model of both processes able to bring back to the school the necessary intellectual stimulus and for the promotion in schools of a different working culture. The idea is that the satisfaction and wonder of research, of inquiry, of questioning and reflection in a collaborative environment could be part of the, if not daily, common work of science teachers.

The interest that has driven this research is that of imagining a future in which the concept of teacher does not convey the traditional image of someone standing in front of an audience near a blackboard, neither just the “modern” one of someone guiding student’s inquiry and group work, but that of someone whose job is also to be sited in a meeting room discussing with other professionals some students’ evidence on their understanding of heat... or someone actively participating in an online forum about the analogies to use when teaching electricity…. or someone guiding a lesson on project-based learning while a colleague video-tapes so that both could discuss later ways of scaffolding the students’…. We all know teachers that do this; we refer to them as innovative teachers. Most of the teachers that have participated in the previous research projects are these sorts of teachers.... However, even for the ones that participate in a transformation of teaching, what is being done does not form a natural part of the profession … An interesting implication of this research work would be to use the proposed model of professional development in contexts of educational innovation to attempt to change this view. We can start with ourselves, linking professional development with educational innovation in our teacher education programmes.

The technological view of teaching and learning that has been object of critique along this work, that of viewing teachers just as those who deliver ready-made curriculum, has shown not only to be inefficient in terms of student outcomes or disrespectful with teachers’ professionalism, but also profoundly non practical. Despite improvements to be made, in general teachers are well educated professionals (one of the best educated professionals in every society). A lot of money and time is spent in their pre-service and in-service preparation. In this sense, any educational policy

should be interested in making the best of these human resources. Investment in new forms of teacher professional development and science innovation is, in fact, a matter of saving money and harnessing human resources. This should be taken into account when it is argued that, despite liking the ideology and reasoning behind models of professional development and school change as the one proposed here, they are too costly in practice. As in many other situations, not doing anything generally cost much more than doing something.

Finally, there is extensive international literature in the field of Professional Development addressing this process for different teachers in different schools than the Spanish/Catalan ones. Throughout this research work, we have tried to make an effort of analysing this literature from the lenses of our context. However, it is an open question whether some of the international research results we have used to support our argumentation and develop our model really apply in the same way in our context. This sets our future research agenda in a particular direction, that of continuing exploring the relationship between professional development and innovation in science education. It could not be the other way round: all research finishes with new questions, every ending being a new beginning.



SECTION 4. Bibliography

Bibliography

Abd-El-Khalick, F., Bell, R. L. and Lederman, N. G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education*, 82, pp.417–436.

Abd-El-Khalick, F. and Lederman, N. G. (2000). Improving science teachers' conceptions of nature of science: A critical review of the literature, *International Journal of Science Education*, 22, pp.665–701.

Adúriz-Bravo, A., Aisenstein, A., Bianchini, G., López-Arriazu, F., Simón, J. and Valli, R. (2003). *A theoretical conception of 'didactics of science' in continental Europe and Latin America*. ESERA, Netherlands.

Adúriz-Bravo, A. and Izquierdo-Aymerich, M. (2002). Acerca de la didáctica de las ciencias como disciplina autónoma, *Revista Electrónica de Enseñanza de las Ciencias*, 1(3).

Aikenhead, G. S. (1987). A module for teaching scientific decision making, *Bulletin of Science, Technology, and Society*, 7, pp.137–145.

Aikenhead, G. S. (1996). Science Education: Border Crossing into the Subculture of Science, *Studies in Science Education*, 27, pp.1-52.

Anderson, R. D. and Mitchener, C. P. (1994). Research on science teacher education. *Handbook of research on science teaching and learning*. In D. L. Gabel (Ed), New York: Macmillan, pp. 3-44.

Appleton, K. and Asoko, H. (1996). A case study of a teacher's progress towards using a constructivist view to inform teaching about elementary science, *Science Education*, 80(2), pp.165-180.

Baird, J. R., Fensham, P. J., Gunstone, R. F. and White, R. T. (1991). The importance of reflection in improving science teaching and learning. *Journal of Research in Science Teaching*, 28(2), pp.163-182.

Ball, D. L. and Cohen, D. K. (1999). Developing practice, developing practitioners. *Teaching as the learning profession. Handbook of policy and practice*. In L. Darling-Hammond and G. Sykes (Eds), San Fransisco: Jossey-Bass, pp.3-32.

Barroso, J. (2002). Reitores, presidentes e directores: evolução e paradoxos de uma função, *Administração Educacional*, 2, pp.91-107.

Barrow, L. H. (2006). A Brief History of Inquiry: From Dewey to Standards, *Journal of Science Teacher Education* 17, pp.265-278.

Bell, B. (1998). Teacher development in Science Education. *International Handbook of Science Education*. In B. J. Fraser and K. G. Tobin (Eds), London: Kluwer Acad. Publishers. II, pp. 681-693.

Bell, B. and Gilbert, J. (1996). *Teacher Development. a Model from Science Education*. London: Falmer Press.

Biddle, B. J., Godd, T. L. and Goodson, I. F., (Eds). (1997). *International handbook of teachers and teaching*. Springer International Handbooks of Education. Dordrecht: Kluwer Academic Publishers.

Black, P. and Atkin, J. M. (1996). *Changing the subject. Innovations in Science, Mathematics and Technology education*. London: Routledge.

Bolam, R., McMahon, A., Stoll, L., Thomas, S., Wallace, M., Hawkey, K. and Greenwood, A. (2005). *Creating and Sustaining Effective Professional Learning Communities. DfES Research Report RR637*. Bristol: University of Bristol.

Borko, H. (2004). Professional Development and Teacher Learning: Mapping the Terrain, *Educational Researcher*, 33(8), pp. 3-15.

Brandes, G. and Seixas, P. (1998). Subjects and disciplines: Asymemetries in a collaborative curriculum development project, *Teachers and Teaching*, 4(1), pp.95.

Bransford, J. D., Brown, A. L. and Cocking, R. R., (Eds). (1999). *How people learn. Brain, mind, experience and school.* Washington, D.C: National Academy Press.

Brown, A. L. (1997). Transforming Schools Into Communities of Thinking and Learning About Serious Matters, *American Psychologist*, 52(4), pp.399-413.

Brown, A. L. and Campione, J. C. (1996). Psychological theory and the design of innovative learning environments: on procedures, principles, and systems. *Innovations in Learning: New Environments for Education*. In L. Schauble and R. Glaser (Eds), Mahwah, NJ: Erlbaum, pp.289-325.

Bruner, J. S. (1966). *On knowing: essays for the left hand.* New York: Atheneum.

Bybee, R. W. (2006). The Science Curriculum: Trends and Issues. In J. Rhoton and P. Shaneck: *Teaching Science in the 21st Century*. NSTA Press.

Calderhead, J., (Ed). (1987). *Exploring Teachers' Thinking*. London: Cassell Educational Limited.

Calderhead, J. (1996). Teachers: Beliefs and knowledge. *Handbook of educational psychology*. In D. Berliner and R. Calfee (Eds), New York: Simon & SchusterMacmillan, pp.709–725.

Calderhead, J. and Gates, P., (Eds). (1993). *Conceptualising Reflection in Teacher Development*. London: The Palmer Press.

Calderhead, J. and Shorrock, S. B., (Eds). (1997). *Understanding Teacher Education: Case Studies in the Professional Development of Beginning Teachers.* London: Routledge.

Calgren, I. (1999). Professionalism and teachers as designers, *Journal of Curriculum Studies*, 31(1), pp.43-56.

Clandinin, D. J. (1986). *Classroom practice: Teacher images in action*. London: Falmer Press.

Clandinin, D. J. and Connelly, F. M. (1987). Teachers' personal knowledge: What counts as personal in studies of the personal, *Journal of Curriculum Studies* (19), pp.487-500.

Clandinin, D. J. and Connelly, F. M. (1992). Teacher as Curriculum Maker. *Handbook of Research on Curriculum*. In P. W. Jackson (Ed), New York: MacMillan, pp.363-401.

Clark, C. M. and Peterson, P. L. (1986). Teachers' thought processes. *Handbook of research on teaching*. In M. C. Wittrock (Ed), New York: Macmillan, pp.255-296.

Cochran-Smith, M. (2000). The Future of Teacher Education: framing the questions that matter, *Teaching Education*, 11(1), pp.13-24.

Cochran-Smith, M., Feiman-Nemser, S., McIntyre, D. J. and Demers, K. E., (Eds). (1999). *Handbook of Research on Teacher Education. Enduring Questions in Changing Contexts*. London: Roudledge.

Cochran-Smith, M. and Lytle, S. (1999). Relationships of knowledge and practice: teacher learning in communities. *Review of Research in Education.* In A. Iran-Nejad and P. D. Pearson (Eds), Washington DC: American Educational Research Association, pp.249-305.

Cohen, D. K. and Hill, H. C. (1998). *State policy and classroom performance: Mathematics reform in California*: Consortium for Policy Research in Education.

Cohen, L., Manion, L. and Morrison, K. (2007). *Research Methods in Education*. London: Routledge.

Coll, C. and Porlán, R. (1998). Alcance y perspectivas de una reforma educativa: la experiencia española., *Investigación en la Escuela*, 36, pp. 5-29.

Copeland, W. D., Birmingham, C., De La Cruz, E. and Lewin, B. (1993). The reflective practitioner in teaching: Toward a research agenda. *Teaching and Teacher Education*, 9(4), pp.347-359.

Copello, M. I. and Sanmartí, N. (2001). Fundamentos de un modelo de formación permanente del profesorado de ciencias centrado en la reflexión dialógica sobre las concepciones y las prácticas, *Enseñanza de las Ciencias*, 19(2), pp.269- 284.

Couso, D. (2002a). *Análisis del contenido del discurso de los profesores de ciencias de secundaria en el diseño de unidades didácticas de forma cooperativa*. Facultat de Ciències de l'Educació. Bellaterra: Universitat Autònoma de Barcelona. Master Thesis.

Couso, D. (2002b). La Comunidad de Aprendizaje Profesional. Una propuesta socioconstructivista de desarrollo profesional del profesorado. *Pensamiento y conocimiento de los profesores. Debate y perspectivas Internacionales.* In A. Perafan and A. Adúriz-Bravo (Eds), Bogotá: Universidad Pedagógica Nacional - Colciencias, pp.79-100.

Couso, D. (2008a). Authentic collaboration: a promising paradigm for physics education reform, *International Newsletter on Physics Education (ICPE, IUPAP)*, 56, pp.7-9.

Couso, D. (2008b). *Authentic collaboration: implications and results of a promising paradigm for Science Education reform and research (Keynote lecture)*. International GIREP 2008 Conference: Physics Curriculum Design, Development and Validation. Nicosia (Cyprus): University of Cyprus.

Couso, D. and Pintó, R. (2007). Teachers' Collaborative Reflections about School-Based Science Innovation in Spain. *Professional Development and School Improvement.* In M. Lang, D. Couso, D. Elster, G. Mooney-Simmie, U. Klinger and P. Szybek (Eds), Wien: Studienverlag, pp.75-118.

Couso, D. and Pintó, R. (*in press*). Análisis del Contenido del Discurso Cooperativo de los Profesores de Ciencias en Contextos de Innovación Didàctica, *Enseñanza de la Ciencias*.

Charles, K. J. and Shane, P. M. (2006). Best Practices for Professional Development for the 21st Century. *Teaching Science in the 21st Century*. In J. Rhoton and P. Shaneck: NSTA Press.

Chevallard, Y. (1991). *La transposition didactique: du savoir savant au savoir enseigné*. Paris: La Pensée Sauvage.

Darling-Hammond, L. (1997). School reform at the crossroads: Confronting the central issues of teaching, *Educational Policy*, 11(2), pp.151-166.

Darling-Hammond, L. (1999). Target Time Toward Teachers, *Journal of Staff Development*, 20(2), pp.31-36.

Darling-Hammond, L. (2006). Constructing 21st Century Teacher Education, *Journal of Teacher Education*, 57(3), pp.300-314.

Darling-Hammond, L. and Sykes, G., (Eds). (1999). *Teaching as the Learning Profession: Handbook of Policy and Practice*. S. Francisco Jossey-Bass.

Davis, K. S. (2003). ''Change Is Hard'': What Science Teachers Are Telling Us About Reform and Teacher Learning of Innovative Practices, *Science Education*, 87(1), pp.3-30.

Day, C. (1999a). *Developing Teachers. The Challenge of Lifelong Learning*. London: Roudledge.

Day, C. (1999b). Professional Development and Reflective Practice: purposes, processes and partnerships, *Pedagogy, Culture & Society* 7(2), pp.221-233.

Donnelly, J. (2000). Departmental characteristics and the experience of secondary science teaching, *Educational Researcher*, 42(3), pp.261-273.

Driver, R., Asoko, H., Leach, J., Mortimer, E. and Scott, P. (1994). Constructing Scientific Knowledge in the Classroom, *Educational Researcher,* 23(7), pp.5-12.

Duffee, L. and Aikenhead, G. (1992). Curriculum change, student evaluation, and teacher practical knowledge, *Science Education*, 76, pp.493-506.

Duschl, R. (1990). *Restructuring Science Education*. New York: Teachers College Press.

Ebbutt, D. (1985). Educational action research: some general concerns and specific quibbles. *Issues in Educational Research. Qualitative Methods*. In R. Burgess (Eds), Lewes: Falmer, pp.152-174.

Elliott, J. (1991). *Action Research for Educational Change*. Milton Keynes: Open University Press.

Elliott, J. (Eds). (1993). *Reconstructing Teacher Education*. London: Falmer Press.

Engeström, Y. (1994). Teachers as collaborative thinkers: Activity-theoretical study of an innovative teacher team. *Teachers' Minds and Actions: Research on Teachers' Thinking and Practice*. In I. Carlgren, G. Handal and S. Vaage (Eds), London: The falmer press.

Engeström, Y. (2001). Expansive Learning at Work: toward an activity theoretical reconceptualization, *Journal of Education and Work*, 14(1).

Escudero, J. M. (2004). Claves complementarias para hablar de la dirección de los centros escolares, *Enseñanza. Anuario Interuniversitario de Didáctica*, 22, pp.139-158.

Falk, B. (2004). A passion for inquiry in an era of 'right answers': Inquiring about teachers inquiring about their practice, *Teacher Education Quarterly*, 31((4)), pp.73-84.

Fensham, P. J. (2004). *Defining and Identity. The Evolution of Science Education as a Field of Research*. Dordrech: Kluwer.

Fensham, P. J. (2007). *Competences, from within and without: new challenges and possibilities for scientific literacy*. Promoting Scientific Literacy: Science Education Research in Transaction. Linnaeus Tercentenary Symposium, Uppsala, Sweden, Uppsala University.

Fenstermacher, G. D. (1994). The Knower and the Known: The Nature of Knowledge in Research on Teaching. *Review of Research in Education*. In L. Darling-Hammond (Ed), Washington, D.C.: American Educational Research Association. 20, pp.3-56.

Fenstermacher, G. D. (1999). Teaching on Both Sides of the Classroom Door. *The Beat of a Different Drummer: Essays on Educational Renewal in Honor of John I. Goodlad*. In K. Sirotnik and R. Soder (Eds), New York: Peter Lang, pp.185-196.

Fink, D. (2000). *Good schools/real schools: Why school reform doesn't last*. New York: Teachers College Press.

Fogarty, R. (2001). The rooms of change, *Journal of Staff Development*, 22(3).

Fullan, M. and Hargreaves, A. (1992). *Teacher development and Educational Change*. London: Routledge.

Fullan, M. G. (1992). *Successful School Improvement. The implementation perspective and beyond.* Buckingham: Open University Press.

Fullan, M. G. (2001). *The New Meaning of Educational Change*. London: RoutledgeFalmer.

Furió, C. (1994). Tendencias actuales en la formación del profesorado de ciencias, *Enseñanza de las Ciencias*, 12 (2), pp.188-199.

Furió, C. and Carnicer, J. (2002). El Desarrollo Profesional del Profesor de Ciencias Mediante Tutorías de Grupos Cooperativos. Estudio de Ocho Casos, *Enseñanza de las Ciencias*, 20(1), pp.47-73.

Furió, C. and Gil, D. (1989). La didáctica de las ciencias en la formación inicial del profesorado: una orientación y un programa teóricamente fundamentados, *Enseñanza de las Ciencias*, 7(3), pp.257-265.

Furió, C., Vilches, A., Guisasola, J. and Romo, V. (2001). Finalidades de la enseñanza de las ciencias en la Secundaria obligatoria. ¿Alfabetización científica o preparación propedéutica?, *Enseñanza de las Ciencias*, 19(3), pp.365-376.

Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F. and Yoon, K. S. (2001). What Makes Professional Development Effective? Results From a National Sample of Teachers, *American Educational Research Journal*, 38(4), pp.915-945

Gess-Newsome, J. and G. Lederman, N. (1999). *Examining Pedagogical Content Knowledge: The Construct and Its Implications for Science Education*. Dordrecht: Kluwer Academic Publishers.

Giere, R. (1988). *Explaining Science. A Cognitive Approach*. Chicago: University of Chicago Press.

Giere, R. (1992). Cognitive Models of Science. *Cognitive Models of Science*. In R. Giere (Ed), Minneapolis: University of Minnesota Press.

Gil, D. (1991). ¿Qué hemos de saber y saber hacer los profesores de ciencias?, *Enseñanza de las Ciencias*, 9(1), pp.69-77.

Gil, D. (1993). Aportaciones de la didáctica de las ciencias a la formación del profesorado. *Las didácticas específicas en la formación del profesorado*. In L. Montero and J. M. Vez (Eds), Santiago: Tórculo, pp.277-293.

Gil, D., Carrascosa Alís, J., Dumas-Carré, D., Furió, C., Gallego Badillo, R., Gené, A., González, E. M., Guisasola, J., Martínez Torregrosa, J., Pessoa de Carvalho, A. M., Salinas, J., Tricárico, H. and Valdés, P. (1999). ¿Puede hablarse de consenso constructivista en la educación científica?, *Enseñanza de las Ciencias*, 17(3).

Gil, D., Carrascosa, J. and Martínez, F. S. (2000). La didáctica de las ciencias: una disciplina emergente y un campo específico de investigación. *Didáctica de las ciencias: teoría y práctica de la enseñanza de las ciencias*. In J. Perales and P. Cañal (Eds), Alcoy: Marfil.

Gil, D., Furió, C. and Gavidia, V. (1998). El profesorado y la reforma educativa en España, *Investigación en la Escuela*, 36, pp.49-64.

Giles, C. and Hargreaves, A. (2006). The Sustainability of Innovative Schools as Learning Organizations and Professional Learning Communities During Standardized Reform, *Educational Administration Quarterly*, 24(1), pp.124-156.

Glatthorn, A. (1995). Teacher development. *International encyclopedia of teaching and teacher education*. In L. Anderson (Ed), London: Pergamon Press.

Goodson, I. F. (1992). Sponsoring the Teachers' Voice: Teachers' Lives and Teacher Development. *Understanding Teacher Development*. In A. Hargreaves and M. Fullan (Eds), New York and London: Teachers College Press, pp.110-121.

Goodson, I. F. and Cole, A. L. (1994). Exploring the Teacher's Professional Knowledge: Constructing Identity and Community, *Teacher Education Quarterly*, 21(1), pp.85-105.

Gore, J. and Zeichner, K. (1991). Action research and reflective teaching in preservice teacher education. A case study from the United States, *Teaching and Teacher Education*, 7, pp.119-136.

Grossman, P. and Stodolsky, S. S. (1995). Content as Context: The Role of School Subjects in Secondary School Teaching, *Educational Researcher*, 24(8), pp.5-23.

Grossman, P., Wineburg, S. and Woolworth, S. (2000). *What Makes Teacher Community Different from a Gathering of Teachers?* Center for the Study of Teaching and Policy, University of Washington.

Grossman, P., Wineburg, S. and Woolworth, S. (2001). Toward a Theory of Teacher Community, *Teachers College Record*, 103(6), pp.942-1012.

Gunstone, R. F. and Northfield, J. (1994). Metacognition and learning to teach, *International Journal of Science Education*, 16(5), pp.523 - 537.

Guskey, T. R. (2000). *Evaluating Professional Development*. Thousand Oaks, CA.: Corwin Press.

Guskey, T. R. (2002). Professional Development and Teacher Change, *Teachers and Teaching: theory and practice*, 8(3/4).

Guskey, T. R. and Sparks, D. (1996). Exploring the Relationship Between Staff Development and Improvements in Student Learning, *Journal of Staff Development*, 17(4), pp.34-38.

Haberman, M. (1992). Critical Introduction. *Successful School Improvement. The implementation perspective and beyond.* In M. G. Fullan (Ed), Buckingham: Open University Press.

Hansen, K. H. (1999). The Challenge of Subject Integration to Teacher Socialization and Professional Development. *Changing Schools/Changing Practices: Perspectives on Educational Reform and Teacher Professionalism*. In M. Lang,

J. Olson, H. Hansen and W. Bünder (Eds), Louvain: Garant Publishers, pp.141-148.

Hargreaves, A. (1978). *Las relaciones interpersonales en la Educación*. Madrid: Narcea.

Hargreaves, A. (1994a). *Changing teachers, changing times. Teachers work and culture in the postmodern age.* New York, N.Y.: Teachers College Press.

Hargreaves, A. (2007). Sustainable Professional Learning Communities. *Professional Learning Communities. Divergences, Depth and Dilemmas*. In L. Stoll and K. S. Louis (Eds), New York, N.Y.: Open University Press, pp.181-196.

Hargreaves, A. and Fink, D. (2006). *Sustainable leadership*. London: Wiley & Sons

Hargreaves, A. and Fullan, M., (Eds). (1992). *Understanding Teacher Development.* London and New York: Teachers College Press.

Hargreaves, D. (1999). The knowledge creating school, *British Journal of Educational Studies*, 47(2), pp.122-144.

Hargreaves, D. H. (1994b). The New Professionalism: The Synthesis of Professional and Institutional Development, *Teaching and Teacher Education*, 10(4), pp.423-438.

Harrison, C., Hofstein, A., Eylon, B.-S. and Simon, S. (2008). Evidence-Based Professional Development of Science Teachers in Two Countries, *International Journal of Science Education*, 30(5), pp.577-591.

Hatton, N. and Smith, D. (1995). Reflection in teacher education: towards definition and implementation, *Teaching and Teacher Education*, 11(1), pp.33-49.

Hawley, W. D. and Valli, L. (1999). The Essentials of Effective Professional Development. A New Consensus. *Teaching as the Learning Profession. Handbook of Policy and Practice.* In L. Darling-Hammond and G. Sykes (Eds), San Francisco: Josey-Bass Publishers, pp.128-150.

Helms, J. V. (1998). Science-and Me: Subject Matter and Identity in Secondary School Science Teachers, *Journal of Research in Science Teaching*, 35(7), pp.811-834.

Hennessy, S. (1993). Situated cognition and cognitive apprenticeship: Implications for classroom learning, *Studies in Science Education*, 22, pp.1-41.

Henze, I., van Driel, J. H. and Verloop, N. (2007). Science Teachers' Knowledge about Teaching Models and Modelling in the Context of a New Syllabus on Public Understanding of Science, *Research in Science Education*, 37(2), pp.99-122.

Hodson, D. (1988). Toward a philosophically more valid science curriculum, *Science Education*, 72(1), pp.19-40.

Huberman, M. (1993). The model of the independent artisan in teachers' professional relations. *Teachers' work: Individuals, colleagues and contexts*. In J. W. Little and M. W. McLaughlin (Eds), Teachers College Press: New York.

Huberman, M. (1995). Professional careers and professional development: some intersections. *Professional Development in Education: new paradigms and practices*. In T. R. Guskey and M. Huberman (Eds), New York: Teachers College Press, pp.193-224.

Huberman, M. (1996). Moving mainstream: Taking a closer look at teacher research, *Language Arts*, 73, pp.124-140

Huberman, M., Thompson, C. L. and Weiland, S. (1997). Perspectives on the teaching career. . *International Handbook of Teachers and Teaching.* . In B. J. Biddle, T. L. Good and I. F. Goodson (Eds), Dordrecht: Kluwer, pp.11-78.

Ingvarson, L. (1998). Professional development as the pursuit of professional standards: The standard-based professional development system", *Teaching and Teacher Education*, 14(1), pp.127-140.

Ingvarson, L., Meiers, M. and Beavis, A. (2005). Factors affecting the impact of professional development programs on teachers' knowledge, practice, student outcomes & efficacy, *Education Policy Analysis Archives*, 13(10).

Izquierdo-Aymerich, M. (2005). Hacia una teoría de los contenidos escolares, *Enseñanza de las ciencias*, 23(1), pp.111-122.

Izquierdo-Aymerich, M. (2008). ¿Qué formación científica para el profesorado de secundaria?, *Cuadernos de pedagogía*, 381, pp.93-95.

Izquierdo-Aymerich, M. and Adúriz-Bravo, A. (2003). Epistemological Foundations of School Science, *Science & Education*, 12, pp.27-43.

Izquierdo-Aymerich, M., Espinet, M., García, M. P., Pujol, R. M. and Sanmartí, N. (1999). Caracterización y Fundamentación de la Ciencia Escolar, *Enseñanza de las Ciencias*, special issue, pp.79-92.

Izquierdo-Aymerich, M., Márquez, C. and Espinet, M. (2003). Comunicación multimodal en la clase de ciencias: el ciclo del agua, *Enseñanza de las ciencias*, 21(3), pp.371-386.

Izquierdo-Aymerich, M., Sanmartí, N. and Espinet, M. (1999). Fundamentación y Diseño de las Prácticas Escolares de Ciencias Experimentales, *Enseñanza de las Ciencias*, 17(1), pp.45-59.

Jimenez-Aleixandre, M. P. and Sanmartí, N. (1995). The development of a new science curriculum for secondary school in Spain: opportunities for change, *International Journal of Science Education*, 17(5), pp.647-661.

Jorba, J., Gómez, I. and Prat, A., (Eds). (1998). *Parlar i escriure per aprendre. Ús de la llengua en situació d'ensenyament-aprenentatge des de les àrees curriculars.* . Bellaterra: ICE-UAB.

Jorba, J. and Sanmartí, N. (1996). *Enseñar, aprender y evaluar: un proceso de regulación continua: propuestas didácticas para las áreas de ciencias de la naturaleza y matemáticas*. Madrid: Ministerio de Educación, Cultura y Deportes.

Karplus, R. (1977). Science teaching and the development of reasoning, *Journal of Research in Science Teaching*, 14(2), pp.169-175.

Kemmis, S. (1997). Action Research. *Educational Research, Methodology, and Measurement: An International Handbook*. In J. P. Keeves (Ed), Oxford: Elsevier Science.

Kemmis, S. and McTaggart, R., (Eds). (1981). *The Action Research Planner*. Greelong, Vic.: Deakin University Press.

Kemmis, S. and McTaggart, R., (Eds). (1992). *The Action Research Planner*. Greelong, Vic: Deakin University Press.

Kennedy, M. (1998a). *Form and substance in in-service teacher education. Research monograph No. 13*. Arlington, VA: National Science Foundation.

Kennedy, M. M. (1998b). *The relevance of content in inservice teacher education*. Annual meeting of the American Educational Research Association (AERA). San Diego, C.A.

Knapp, M. S. (1997). Between systemic reforms and the mathematics and science classroom: The dynamics of innovation, implementation, and professional learning, *Review of Educational Research*, 67(2), pp.227-.

Lang, M. (2000). Mediated Exchange and Reflective Collaboration: a model of science teaching development, *Teachers and Teaching: theory and practice*, 6(1), pp.9-22.

Lang, M. (2007). How to improve Science Teaching in Europe: Focussing on teachers' voices in professional development. *Professional Development and School Improvement. Science teachers' voices in school-based reform.* In M. Lang, D. Couso, D. Elster, G. Mooney-Simmie, U. Klinger and P. Szybek (Eds), Innsbruck: StudienVerlag, pp.7-28.

Lang, M., Drake, S. and Olson, J. (2006). Discourse and the New Didactics of Scientific Literacy, *Journal of Curriculum Studies*, 38(2), pp.177-189

Lang, M. and Olson, J. (2000). Integrated Science Teaching as a Challenge for Teachers to Develop New Conceptual Structures, *Research in Science Education*, 30(2), pp.213-224.

Lang, M., Olson, J., Hansen, H. and Bünder, W., (Eds). (1999). *Changing Schools / Changing Practices: Perspectives on Educational Reform and Teacher Professionalism.* Louvain: IPN & Garant Publishers.

Lave, J. (1996). The practice of learning. *Understanding practice: Perspectives on activity and context*. In S. Chaiklin and J. Lave (Eds), Cambridge: Cambridge University Press, pp.3–32.

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

Lederman, N. G. (1999). Teachers' understanding of the nature of science and classroom practice: Factors that facilitate or impede the relationship, *Journal of Research in Science Teaching*, 36, pp.916–929.

Lee, V. E. and Smith, J. B. (1996). Collective responsibility for learning and its effects on gains in achievement for early secondary students, *American Journal of Education*, 104(2), pp. 103-147.

Leithwood, K. A. (1992). The principal's role in teachers' development. *Teacher Development and Educational Change*. In M. Fullan and A. Hargreaves (Eds), London: Falmer Press.

Lemke, J. L. (1997). *Aprender a hablar ciencia. Lenguaje, aprendizaje y valores.* Barcelona: Paidós.

Lieberman, A. and Grolnick, M. (1996). Networks and reform in American education, *Teachers College Record*, 98(1), pp.7-45

Little, J. W. (1993). Teachers' Professional Development in a Climate of Educational Reform, *Educational Evaluation and Policy Analysis*, 15(2), pp.129-151.

Little, J. W. (2002). Locating learning in teachers' communities of practice: opening up problems of analysis in records of everyday work, *Teaching and Teacher Education*, 18(8), pp.917-946.

Little, J. W. (2003). Constructions of Teacher Leadership in Three Periods of Policy and Reform Activism, *School Leadership & Management*, 23(4), pp.401-419.

Little, J. W. and Bartlett, L. (2002). Career and Commitment in the Context of Comprehensive School Reform, *Teachers and Teaching: theory and practice*, 8(3/4), pp.345-354.

Lord, B. (1994). Teachers' professional development: Critical colleagueship and the role of professional communities. *The future of education: Perspectives on national standards in education.* In N. Cobb (Ed), New York, N.Y.: College Entrance Examination Board, pp.175-204.

Lortie, D. (1975). *Schoolteacher*. Chicago: University of Chicago Press.

Loucks-Horsley, S., Love, N., Stiles, K. E., Hewson, P. W. and Mundry, S., (Eds). (2003). *Designing Professional Development for Teachers of Science and Mathematics*. Thousand Oaks, C.A.: Corwin Press.

Loucks-Horsley, S. and Matsumoto, C. (1999). Research on professional development for teachers of mathematics and science: The state of the scene, *School Science & Mathematics*, 99(5), pp.258-271.

Loughran, J. and Gunstone, R. F. (1997). Professional Development in Residence: developing reflection on science teaching and learning, *Journal of Education for Teaching*, 23(2).

Loughran, J. J. (2002). Effective Reflective Practice. In search of meaning in learning about teaching., *Journal of Teacher Education*, 53(1), pp.33-43.

Louis, K. S. and Marks, H. (1998). Does professional community affect the classroom? Teacher work and student work in restructuring schools, *American Journal of Education*, 106(4), pp.532-575.

Manning, B. H. and Payne, B. D. (1993). A Vygotskian-Based Theory of Teacher Cognition: Toward the Acquisition of Mental Reflection and Self-Regulation, *Teaching and Teacher Education*, 9(4), pp.361-371.

Manouchehri, A. (2002). Developing teaching knowledge through peer discourse, *Teaching and Teacher Education*, 18(6), pp.715-737.

Marbà, A. (2008). *La dimensió afectiva de l'aprenentatge de les ciències: actituds i motivacions*. Facultat de Ciències de l'Educació. Bellaterra: Universitat Autònoma de Barcelona. PhD Thesis.

Marcelo, C. (1987). *El pensamiento del profesor*. Barcelona: CEAC.

Marcelo, C. (1993). Cómo conocen los profesores la materia que enseñan. Algunas contribuciones de la investigación sobre conocimiento didáctico del contenido. *Las didácticas específicas en la formación del profesorado.* . In L. Montero and J. M. Vez (Eds), Santiago: Tórculo, pp.151-186.

Márquez, C. and Roca, M. (2006). Plantear preguntas: un punto de partida para aprender ciencias, *Revista Educación y Pedagogía*, 18(45), pp.63-71.

McComas, W. (1998). *The Nature of Science in Science Education. Rationales and Strategies*. Dordrecht: Kluwer.

McComas, W. F. and Olson, J. K. (1998). The nature of science in international science education standards documents. *The nature of science in science education: Rationales and strategies* In W. F. McComas (Eds), The Netherlands: Kluwer Academic Publisher, pp. 41–52.

McLaughlin, M. W. (1991). Enabling professional development: What have we learned? *Staff development for education in the 90's: New demands, new realities, new perspectives*. In A. Lieberman and L. Miller (Eds), New York: Teachers College Press.

McLaughlin, M. W. (1994). Strategic sites for teachers professional development. *Teacher development and the struggle for authenticity: Professional growth and restructuring in the context of change*. In P. P. Grimmett and J. Neufeld (Eds), New York: Teachers College Press, pp.31-51.

McLaughlin, M. W. and Talbert, J. E. (2001). *Professional communities and the work of high school teaching*. Chicago: University of Chicago Press.

McMahon, A., Bolam, R., Abbott, R. and Holly, P. (1984). *Guidelines for review and internal development in schools (primary and secondary school handbooks)*. York Longman/Schools Council.

McNamara, D. (1990). Research on teachers' thinking: Its contribution to educating student teachers to think critically, *Journal of Education for Teaching*, 16(2), pp.147-160.

Mellado, V. (1995). *Análisis del Conocimiento Didáctico del Contenido, en Profesores de Ciencias de Primaria y Secundaria en Formación Inicial*. Cáceres: Universidad de Extremadura.

Mellado, V. (1996). Concepciones y prácticas de aula de profesores de ciencias, en formación inicial, de primaria y secundaria, *Enseñanza de las Ciencias*, 14(3), pp.398-302.

Mellado, V. (1997). Preservice teachers' classroom practice and their conceptions of the nature of science, *Science & Education*(6), pp.331–354.

Mellado, V. (1998). The classroom practice of preservice teachers and their conceptions of teaching and learning science, *Science Education*, 82(197-214).

Mellado, V. (2000). ¿Es adecuada la formación científica del profesorado de ciencias de secundaria para sus necesidades profesionales?, *Alambique*, 24, pp.57-65.

Mellado, V. (2001). ¿Por que a los profesores de ciencias nos cuesta tanto cambiar nuestras concepciones y modelos didácticos?, *Revista Interuniversitaria de Formación del Profesorado*, 40, pp.17-30.

Mellado, V. (2003). Cambio Didáctico del Profesorado de Ciencias Experimentales y Filosofía de la Ciencia, *Enseñanza de las Ciencias*, 21(3), pp.343-358.

Millar, R. (1989). Bending the evidence: The relationship between theory and experiment in science education. *Doing science: Images of science in science education*. In R. Millar (Eds), New York: The Falmer Press, pp.38–61.

Millar, R. and Osborne, J. (1998). *Beyond 2000: Science Education for the Future*. London: King's College.

Mulford, B. and Silins, H. (2003). Leadership for Organisational Learning and Improved Student Outcomes-What Do We Know?, *Cambridge Journal of Education*, 33(2), pp.176-195.

Munby, H., Cunningham, M. and Lock, C. (2000). School science culture: A case study of barriers to developing professional knowledge, *Science Education*, 84(2), pp.193-211.

Munby, H. and Russell, H. (1998). Epistemology and context in research on learning to teach science. *International Handbook of Science Education*. In B. J. Fraser and K. G. Tobin (Eds), London: Kluwer Acad. Publisher. II, pp. 643-665.

Munby, H., Russell, T. and Martin, A. K. (2001). Teachers' knowledge and how it develops. *Handbook of research on teaching*. In V. Richardson (Eds), Washington, D.C.: American Educational Research Association, pp.877–904.

NCTAF (1996). *What matters most: Teaching for America's future.* Kutztown, P.A.: National Commission on Teaching and America's Future.

Nias, J., Southworth, G. and Yeomans, R. (1989). *Staff relationships in the primary school: A study of organisational cultures*. London Cassell.

Novak, J. D. (1988). Constructivismo humano: un consenso emergente., *Enseñanza de las Ciencias*, 6(3), pp.213-223.

NRC (1996). *National Science Education Standards (NSES)*. Washington, DC: National Academy Press.

NRC (2000). *Inquiry and the national standards.* Washington, DC: National Academy Press.

OECD (2001). *Messages from PISA 2000*. Paris: OECD Publishing

OECD (2004). *Learning for Tomorrow's World. First Results from PISA 2003*. Paris: OECD Publishing.

OECD (2005). *Teachers Matter. Attracting, Developing and Retaining Effective Teachers Education and Training Policy.* Paris: OECD Publishing.

OECD (2006). *Evolution of Student Interest in Science and Technology Studies*. Paris: OECD Publishing.

OECD (2007). *PISA 2006: Science Competencies for Tomorrow's World*. Paris: OECD Publishing.

Ogborn, J. (2002). Ownership and transformation: Teachers using curriculum innovations, *Physics Education*, 37(2), pp.142-146.

Olson, J. (2002). Systemic change/teacher tradition: legends of reform continue, *Journal of Curriculum Studies*, 34(2), pp.129-137.

Palincsar, A. S., Magnusson, S. J., Marano, N., Ford, D. and Brown, N. (1998). Designing a Community of Practice: Principles and Practices of the GIsML Community, *Teaching and Teacher Education*, 14(1), pp.5-

Parke, H. M. and Coble, C. R. (1997). Teachers designing curriculum as professional development: A model for transformational science teaching, *Journal of Research in Science Teaching*, (34), pp.773-790

Perrenoud, P. (1995). *Dix non dits ou la face cachée du métier d'enseignant*. Recherche et Formation, pp.107-124.

Pfundt, H. and Duit, R. (1994). *Bibliography: Students' alternative frameworks and Science Education*. Kiel, Germany: IPN (Institute for Science Education).

Philips, M. and Glickman, C. (1991). Peer coaching: Developmental approach to enhancing teacher thinking, *Journal of Staff Development*, 12, pp.20-25.

Pintó, R. (2005). Introducing curriculum innovations in science: Identifying teachers' transformations and the design of related teacher education, *Science Education*, 89(1), pp.1-12.

Pintó, R., Couso, D. and Gutiérrez, R. (2005). Using Research on Teachers' Transformations of Innovations to Inform Teacher Education. The Case of Energy Degradation, *Science Education*, 89(1), pp.38-55.

Pintó, R. and Gómez, R. (1999). *Teaching about energy in Spanish secondary schools: Teachers' transformations of innovations. STTIS national report WP3. [online]. Retrieved January, 2009, from http://crecim.uab.cat/websttis/*.

Pintó, R., Gutiérrez, R., Ametller, J., Andresen, O., Balzano, E., Boohan, R., Chauvet, F., Colin, P., Couso, D., Giberti, G., Hirn, C., Kolsto, S. D., Monroy, G., Ogborn, J., Quale, A., Rebmann, G., Sassi, E., Stylianidou, F., Testa, I. and Viennot, L.

(2001). *Teachers transformations trends when implementing innovations. STTIS report RW4. [online]. Retrieved January, 2009, from http://crecim.uab.cat/websttis/*.

Pintó, R., Gutiérrez, R. and Couso, D. (2000). *Teaching about energy degradation. STTIS national report WP5. [online]. Retrieved January, 2009, from http://crecim.uab.cat/websttis/*.

Pintó, R., Gutiérrez, R. and Couso, D. (2001). *Teaching about energy conservation and degradation. Using research into teachers' transformations to design material for teacher training*. Third International ESERA Conference on Science Education Research in the Knowledge Based Society, Thessaloniki, Greece, University of Thessaloniki.

Porlán, R. (1993). *Constructivismo y escuela. Hacia un modelo de enseñanza-aprendizaje basado en la investigación.* Sevilla: Díada editora.

Porlán, R. (1998). Pasado, presente y futuro de la didáctica de las ciencias, *Enseñanza de las Ciencias*, 16(1), pp.165-175.

Porlán, R. and Rivero, A. (1998). *El conocimiento de los profesores*. Sevilla: Diada.

Posner, G. J., Strike, K. A., Hewson, P. W. and Gertzog, W. A. (1982). Accomodation of a scientific conception: Toward a theory of conceptual change, *Science Education*, 66, pp.211-227.

Pro Bueno, A. (2006). Perfil de la «reforma logse» y perfil de uso : los fundamentos de los proyectos curriculares de física y química en centros de secundaria, *Enseñanza de las Ciencias*, 24(3), pp.337-356.

Pro Bueno, A. (2007). Los contenidos de los proyectos curriculares de física y química en secundaria en la implantación de la reforma LOGSE., *Enseñanza de las Ciencias*, 25(3), pp.367-386.

Putnam, R. and Borko, H. (1997). Teacher learning: Implications of the new view of cognition. *The international handbook of teachers and teaching*. In B. J. Biddle, T. L. Good and I. F. Goodson (Eds), Dordrecht: Kluwer.

Putnam, R. and Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teacher learning?, *Educational Researcher*, 29(1), pp.4-15.

Roberts, D. A. (2007). *Openning Remarks*. Promoting Scientific Literacy: Science Education Research in Transaction. Linnaeus Tercentenary Symposium, Uppsala, Sweden, Uppsala University.

Roca, M. (2005). Cuestionando las cuestiones, *Alambique*, 45, pp.9-17.

Rogan, J. M. (2007). How Much Curriculum Change Is Appropriate? Defining a Zone of Feasible Innovation, *Science Education*, 91(3), pp.439.

Saha, L. J. and Dworkin, A. G., (Eds). (2009). *International Handbook of Research on Teachers and Teaching*. Springer International Handbooks of Education.

Sanmartí, N., Calvet, M., Custodio, E., Estanya, J. L., Franco, R., García, M. P., Izquierdo, M., Màrquez, C., Oliveras, B., Ribas, N., Roca, M., Sardà, A., Solsona, N. and Via, A. (2003). *Aprendre ciències tot aprenent a escriure ciència.* Barcelona: Edicions 62.

Sanmartí, N. and Izquierdo-Aymerich, M. (1997). Reflexiones en torno a un modelo de ciencia escolar, *Investigación en la escuela*, 32, pp. 51-62.

Sanmartí, N., Izquierdo, M. and García, M. P. (1999). Hablar y escribir: Una condición necesaria para aprender ciencias, *Cuadernos de pedagogía*, 281, pp.54-58.

Sardà, A. and Sanmartí, N. (2000). Enseñar a argumentar científicamente: un reto de las clases de ciencias, *Enseñanza de las Ciencias* (18), pp.405-422.

Schoenfeld, A. H. (2004). Multiple learning communities: students, teachers, instructional designers, and researchers, *Journal of Curriculum Studies*, 36(2), pp.237-255.

Schon, D. A. (1983). *The Reflective Practitioner: how professionals think in action.* New York: Basic Books.

Schön, D. A. (1983). *The reflective practitioner. How professionals think in action*. New York: Basic Books.

Schön, D. A. (1987). *Educating the reflective practitioner. Toward a new design for teaching and learning in the professions.* San Francisco: Jossey Bass.

Schreiner, C. and Sjøberg, S. (2004). *Sowing the seeds of ROSE. Background, Rationale, Questionnaire Development and Data Collection for ROSE (The Relevance of Science Education) - a comparative study of students' views of science and science education*. Oslo, Norway: Dept. of Teacher Education and School Development, University of Oslo.

Schreiner, C. and Sjøberg, S. (2007). Science education and youth's identity construction - two incompatible projects?. *The Re-emergence of Values in the Science Curriculum*. In A. D. Corrigan, J. Dillon and R. Gunstone (Eds), Rotterdam: Sense Publishers, pp.1-17.

Seashore, K., Anderson, A. R. and Riedel, E. (2003). *Implementing Arts for Academic Achievement: The impact of mental models, professional community and interdisciplinary teaming*: Paper prepared for Minneapolis Public Schools, University of Minnesota, CAREI.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching, *Educational researcher*, 15, pp.4-14.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform., *Harvard Educational Review*, 57(1), pp.1-22.

Shulman, L. S. and Shulman, J. H. (2004). How and what teachers learn: a shifting perspective, *Journal of Curriculum Studies*, 36(2), pp.257-271.

Solomon, J. (1987). Social influences on the construction of pupils' understanding of science, *Studies in Science Education*, 14, pp.63-82.

Southerland, S. A., Gess-Newsome, J. and Johnston, A. (2003). Portraying science in the classroom: The manifestation of scientists' beliefs in classroom practice, *Journal of Research in Science Teaching*, 40, pp.669–691.

Sparks, D. and Loucks-Horsley, S. (1989). Five Models of Staff Development for Teachers, *Journal of Staff Development*, 10(4), pp.40-57.

Stodolsky, S. S. (1988). *The Subject Matters: Classroom Activity in Math and Social Studies*. Chicago: University of Chicago Press.

Stoll, L. (1999). School culture: black hole or fertile garden for improvement. *School Culture*. In J. Prosser (Eds), London: Paul Chapman.

Stoll, L., Bolam, R., McMahon, A. and Wallace, M. (2006). Professional Learning Communities: A Review of the Literature, *Journal of Educational Change*, 7, pp.221–258.

Stoll, L. and Louis, K. S. (2007). *Professional learning communities: divergence, depth and dilemmas*. New York: Open University Press.

Supovitz, J. A. and Turner, H. M. (2000). The Effects of Professional Development on Science Teaching Practices and Classroom Culture, *Journal of Research in Science Teaching*, 37(9), pp.963-980.

Terhart, E. (1999). Developing a Professional Culture. *Changing schools,/Changing practices: Perspectives on Educational Reform and Teacher Professionalism*. In M. Lang, J. Olson, H. Hansen and W. Bünder (Eds), Louvain: Garant Publishers, pp.27-39.

Thomas, G., Wineburg, S., Grossman, P., Myhre, O. and Woolworth, S. (1998). In the company of colleagues: an interim report on the development of a community of teacher learners, *Teaching and Teacher Education*, 14(1), pp.21-32.

Tobin, K. (1990). Social constructivist perspectives on the reform of science education, *Australian Science Teachers Journal*, 36(4), pp.29-35.

Tobin, K. and Dawson, G. (1992). Constraints to curriculum reform: Teachers and the myths of schooling, *Education Technology Research and Development*, 40, pp.81- 92.

Tobin, K. and Espinet, M. (1989). Impediments to change: applications of coaching in high school science teaching, *Journal of Research in Science Teaching*, 26(2), pp.105-120.

Tom, A. R. and Valli, L. (1990). Professional knowledge for teachers. *Handbook of research on teacher education*. In W. R. Houston (Eds), New York: Macmillan, pp.372-392.

Townsend, T. and Bates, R., (Eds). (2007). *Handbook of Teacher Education. Globalization, Standards and Professionalism in Times of Change*. Dordrecht: Springer.

Tsai, C.-C. (2006). Reinterpreting and reconstructing science: Teachers' view changes toward the nature of science by courses of science education, *Teaching and Teacher Education*, 22, pp.363–375.

Valcárcel, M. V. and Sánchez, G. (2000). La formación del profesorado en ejercicio. *Didáctica de las ciencias experimentales*. In F. J. Perales and P. Cañal (Eds), Alcoy: Marfil, pp.557-581.

Valli, L., (Eds). (1992). *Reflective Teacher Education: Cases and Critiques*. Albany, N.Y: State University of New York Press

van Driel, J. H., Beijaard, D. and Verloop, N. (2001). Professional Development and Reform in Science Education: The Role of Teachers' Practical Knowledge, *Journal of Research in Science Teaching*, 38(2), pp.137-158.

Van Manen, M. (1977). Linking ways of knowing with ways of being practical, *Curriculum Inquiry*, 6, pp.205-228.

Vázquez, B., Jiménez, R. and Mellado, V. (2007). El desarrollo profesional del profesorado de ciencias como integración de la reflexión y la práctica: La hipótesis de la complejidad, *Revista Eureka sobre enseñanza y divulgación de las ciencias*, 4(3), pp.372-393.

Vescio, V., Ross, D. and Adams, A. (2008). A review of research on the impact of professional learning communities on teaching practice and student learning, *Teaching and Teacher Education*, 24(1), pp.80-91.

Viennot, L., Chauvet, F., Colin, P. and Rebmann, G. (2005). Designing strategies and tools for teacher training: The role of critical details, examples in optics, *Science Education*, 89(1), pp.13-27.

Villegas-Reimers, E. (2003). *Teacher professional development: an international review of the literature*. Paris: UNESCO. International Institute for Educational Planning, pp.1-197.

Visscher, A. J. and Witziers, B. (2004). Subject departments as professional communities?, *British Educational Research Journal*, 30(6), pp.785-800.

Vygotsky, L. S. (1978). *Mind and society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Wallace, J. and Louden, W. (1992). Science teaching and teachers' knowledge: Prospects for reform of elementary classrooms, *Science Education*, 76, pp.507-521.

Wandersee, J. H., Mintzes, J. J. and Novak, J. D. (1994). Research on alternative conceptions in science. *Handbook of Research on Science Teaching and Learning*. In D. L. Gabel (Ed), Nueva York: MacMillan.

Wasley, P. A., Hampel, R. and Clark, R. (1997). *Kids and School Reform*. San Francisco: Jossey-Bass Publishers.

Weiss, I. R., Banilower, E. R., McMahon, K. C. and Smith, P. S. (2001). *Report of the 2000 National Survey of Science and Mathematics Education*. Chapel Hill, NC: Horizon Research.

Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity.* Cambridge: Cambridge University Press.

Wertsch, J. V. (1988). *Vygotsky and the Social Formation of Mind*: Harvard University Press.

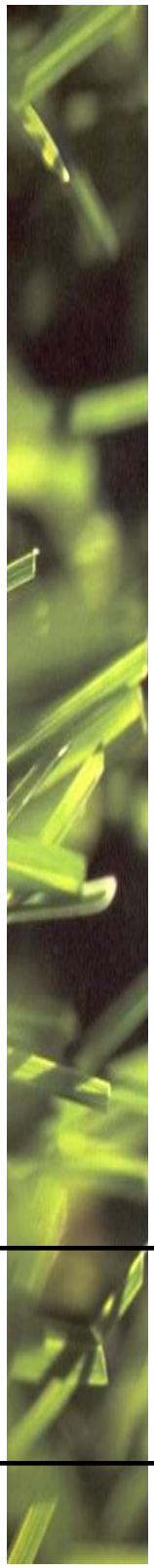
Westheimer, J. (1998). *Among school teachers: Community, autonomy, and ideology in teachers' work*. New York: Teachers College Press.

Wilson, S. M. and Berne, J. (1999). Teacher learning and the acquisition of professional knowledge: an examination of research on contemporary professional development. *Review of Research in Education*. In A. Iran-Nejad and P. D. Pearson (Eds), Washington DC: American Educational Research Association, pp.173-209.

Zeichner, K. (1994). Research on teacher thinking and different views of reflective practice in teaching and teacher education. *Teachers minds and actions: Research on teacher's thinking and practice*. In I. Carlgren, G. Handal and S. Vaage (Eds), London: Falmer Press.

Zeichner, K. M. (1983). Alternative paradigms of teacher education, *Journal of Teacher Education*(34), pp.3-9.


Hargreaves
Izquierdo-Aymerich
Sanmartí
Mellado
Couso
Pintó
Lang
Gil
Espinet
Calderhead
Huberman
Woolworth
Putnam
Bolam
Sardà
Loucks-Horsley
Jorba
Ogborn
Ingvarson
Fenstermacher
Fink
Giere
Zeichner
Wallace
Sparks
Borko
OECD
Gutiérrez
Olson
Furió
Darling-Hammond
Lederman
Valli
Grossman
McMahon
Fullan
Kemmis
Gunstone
García
Smith
Clark
Cohen
Clandinin
Chauvet
Verloop
Sjøberg
Márquez
Rebmann
Schreiner
Novak
Colin
McComas
Driel
Martínez
Thomas
Connelly
Abd-El-Khalick
Pro
Stodolsky
Hewson
Marcelo
Elliott
Cochran-Smith
McLaughlin
Porlán
Guskey
Munby
Viennot
Anderson
Bueno
Hansen
Russell
Stoll
Louis
Izquierdo
Aikenhead
Day
Fensham
Asoko
Goodson
Adúriz-Bravo
Brown
Little
Bell
Roca
Tobin
Engeström
Gess-Newsome
Guisasola
Kennedy
Loughran
Carrascosa
McTaggart
Shulman
Wineburg
Gómez
Barrow
Boohar
Copeland
Campione
Adams
Bruner
Cole
Davis
Balzano
Ametller
Calvet
Andresen
Cocking
Charles
Barroso
Chevallard
Abbott
Bybee
Badillo
Biddle
Birmar
Allis
Coll
Black
Beijaard
Cruz
Demers
Carmicer
Bartlett
Cunningham
Donnelly
Bünder
Calgren
Capello
Schön
Millar
Baird
Bianchini
Dawson
Appleton
Birmingham
Atkin
Banilower
Desimone
Carvalho
Aisenstein
Bates
Berne
Ball
Brandes
Coble



ANNEXES

Annex 1

Acceptance letter for the presentation of this thesis as a compendium of published papers

UAB **Escola de Postgrau**
Universitat Autònoma de Barcelona

Universitat Autònoma de Barcelona - Registre General Escola de Postgrau
Sortida
014 Núm. 200800017999
20/10/08 08:28:04

Exp. 15875

Sra. Digna Couso Lagarón
Facultat d'Educació - Ed. GL-304
Bellaterra

Vista la instància presentada per na Digna Couso Lagarón de sol·licitud de presentació de tesi doctoral com a compendi de publicacions,

De conformitat amb el que disposa el Text Refós de la Normativa de Doctorat aprovada pel Consell de Govern (última modificació març de 2006),

RESOLC

Acceptar la presentació de la tesi doctoral de na Digna Couso Lagarón com a compendi de publicacions amb els articles següents:

- Pintó, R.; Couso, D. Gutiérrez, R. (2005). "Using Research on Teachers. Transformations of Innovations to Inform Teacher Education. The Case of Energy Degradation". Science Education, 89 (1), p. 38-55.
- Couso, D., Pinto, R. (2007). "Teachers' Collaborative Reflections about School-Based Science Innovation in Spain. A Lang, M.; Couso, D., Elster, D., Mooney-Simmie, G., Klinger, U. &Szybek, P. (Eds.). *Professional Development and School Improvement.* Cap. 3, p. 75-118. Studienverlag: Viena (Àustria).
- Couso, D., Pinto, R. "Análisis del Contenido del Discurso Cooperativo de los Profesores de Ciencias en Contextos de Innovación Didáctica". *Enseñanza de las Ciencias*. Barcelona: ICE-UAB.

La Subcomissió de Postgrau de la Comissió d'Afers Acadèmics,
Per delegació

Escola de Postgrau
Universitat Autònoma de Barcelona

Carles JAIME CARDIEL
Delegat del Rector per a Doctorat

Bellaterra (Cerdanyola del Vallès), 8 d'octubre de 2008

Contra aquesta resolució, que no esgota la via administrativa, les persones interessades poden interposar recurs d'alçada davant l'Excm. i Magfc. Rector de la UAB, en el termini d'un mes, a comptar des del dia següent a la recepció d'aquesta notificació o, si s'escau, des d'un mes, a comptar des del dia següent de la seva publicació, de conformitat amb el que preveu l'article 115 de la Llei 30/1992, de 26 de novembre, de Règim Jurídic de les Administracions Públiques i del Procediment Administratiu Comú, modificada per la Llei 4/1999, de 13 de gener"

Edifici U - Campus de la UAB - 08193 Bellaterra (Cerdanyola del Vallès) - Barcelona. Spain
Tel.: 34 93 581 30 10 - Fax: 34 93 581 34 76
ep.doctorat@uab.es - www.uab.es/postgrau

Annex 2

Summary in English of Publication 3

(Extracted from the paper presented at ESERA Conference 2003, Noordwijkerhout, The Netherlands)

Cooperative work of in-service Secondary School Science Teachers. New tools for analysing content of teachers' discourse.

Couso, D. & Pintó, R. Universitat Autònoma de Barcelona, Spain

Introduction

In modern proposals of in-service Secondary School teachers' development, collaboration among teachers/teacher leaders are mentioned as a central feature (Wilson & Berne, 1999). Many examples of learning and inquiry communities of teachers are found in the recent literature (Cochran-Smith, M. & Lytle S., 1999; Grossman et al., 2001). Modern views of socio-constructivist approaches, together with the assumption of transferability from research-results on students' cooperative learning to the teacher learning field sustain, at least theoretically, the importance of teachers' cooperative environments for teachers' learning. Besides, for complete teacher professional development, the mastering of social interactive skills in the school context is required. Interesting initiatives like the school-based collaboratives (Hargreaves, 1999) rely partially on teachers'/teacher leaders' ability for successful collaboration. This situation, however, contrasts with the short amount of empirical research on teachers' cooperative work.

The research we are carrying on has the aim to increase our knowledge on teachers' collaboration. We present here a first exploratory research-study focused on the content of teachers' discourse in cooperative environments. The following research questions are addressed: What is the content of teacher's discourse generated in their cooperative work and how does this content relate with the achievement of the objectives of the group-work.

Methods

To analyse the content of teachers' discourse in collaborative environments, we have contacted a voluntary and self-managed group of 7 in-service secondary-school science teachers. Teachers work cooperatively to draw up teaching units about the Energy concept with an STS & integrated science perspective. Materials include the use of IT's and stress the value of peer work.

When requested to be observed, teachers in the group asked for our participation, so the strategy for data gathering has been *Observational participation* documented by audio-recording of teachers' meetings and field-notes during/post observation (diary-writing). The documents shared/developed by teachers during the meetings were also gathered. Being this an holistic and descriptive research looking for meaning in a natural context, our methodological framework is interpretative.

Results

The verbal data gathered during teachers' cooperative work was transcribed and analysed to find categories (*Semiotic Spaces* and *Discursive Sequences)* in which classifying the content of teachers' discourse.

Semiotic Spaces have been defined as "big" content-areas related to features of reality in which teachers' discourse has meaning. In our research study, three different Semiotic Spaces were identified:

- Didactical, i.e. teachers' discourse about features of teaching, such as selection/transposition of contents (Chevallard 1985), methodologies for teaching, etc.
- Scientific, i.e. teachers' discourse about scientific concepts.
- Group Strategies, i.e. teachers' discourse about features of cooperation, such as its management, regulation, etc. This speech addresses the development of the group dynamics (also found in previous researches on students' peer-work)

Discursive Sequences come from a deeper level of analysis and constitute our analysis unit. They are defined as sequences of teachers' discourse (not particular speakers' discourse but discourse generated in the group, whoever have produced it) that constitute meaningful units which refer to different features of reality in the same meaning space. For instance, the mentioned selection of content and discussion about methodologies for classroom-work belong to the same Didactical Space but refer to different features of it. Figure 1 shows the categories found.

The identification of the content categories mentioned answer our first research question. The second one, however, requires a different analytical treatment: to find relations between content of teachers' discourse and their actual designing of teaching materials (the objective of the group-work).

To begin with, meetings have been summarised and structured in *Activity Segments* (adapting to the teachers' meeting situation Stodolsky's (1991) idea of behavioural settings in which classroom lessons can be split). We have used these structure to classify different types of teachers' activities, such as the discussion about contents or the actual design of students' worksheets. Comparison among the activities identified and the distribution of content in teachers' discourse presented a major problematic: to find representational tools able to show this distribution *at a glance*, a kind of "discourse content picture" of the meeting. With this aim, we have developed *Histograms of quantity* and *frequency* of discourse and *Thematic Clustering Graphs (TCG's)*.

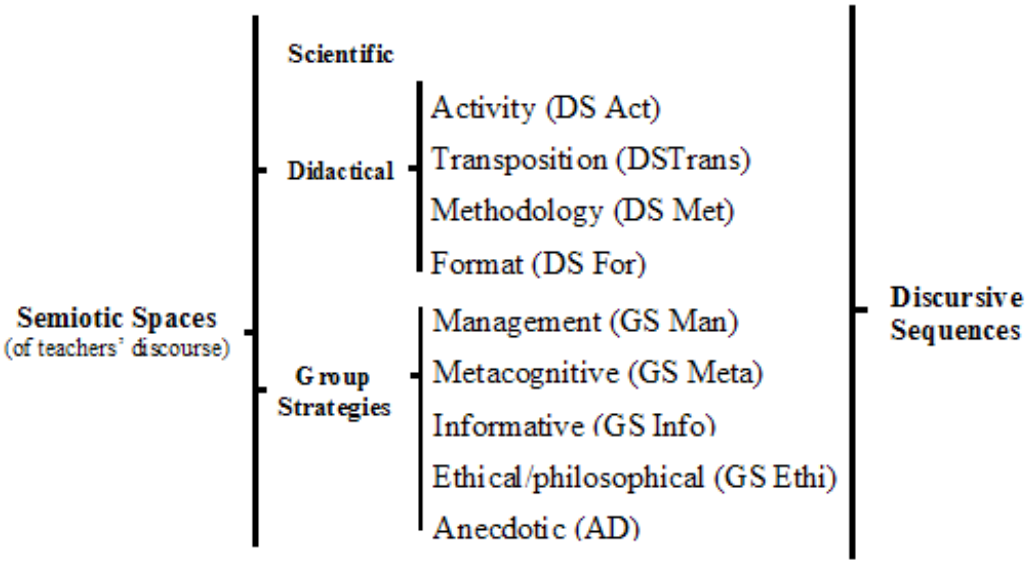


Figure 1: Semiotic Spaces and Discursive Sequences found in teachers' discourse

Histograms show the total amount or total frequency of a particular Discursive Sequence in a meeting. This allows easy comparison between general features of discourse in different types of meeting. *TCG's*, adapted from the Discourse Analysis field (Casalmiglia et al., 1997), show the evolution (in frequency or quantity) of teachers' Discursive Sequences along a meeting. They provide information about *when* (in which type of Activity Segment) teachers speak about *what* (the particular Discursive Sequences of their speech). In both cases quantity is measured in number

of characters from transcription. An example of comparison of two different meetings with these tools follows.

Figures 2 to 5 are histograms of frequency and quantity of teachers' discourse in two different meetings. For the sake of brevity, only the six most relevant Discursive Sequences have been plotted. Figures 6 and 7 show, for the same meetings and categories, evolution of teachers' discourse (*variation among content-categories*) and quantity of each of them (*the horizontal axis measures percentage of discourse*).

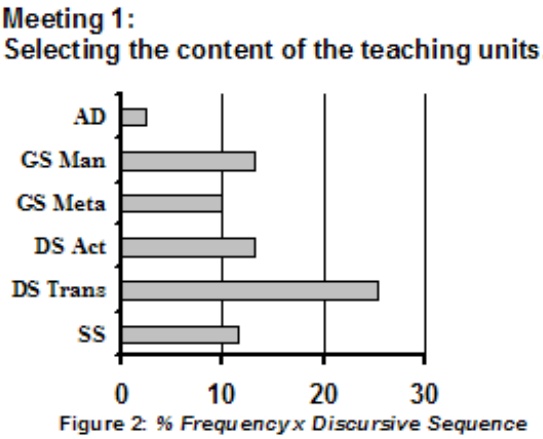


Figure 2: % *Frequency x Discursive Sequence*

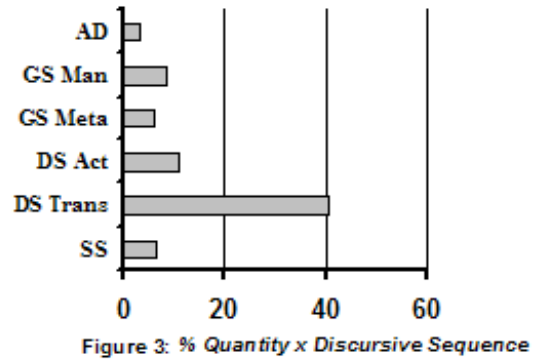


Figure 3: % *Quantity x Discursive Sequence*

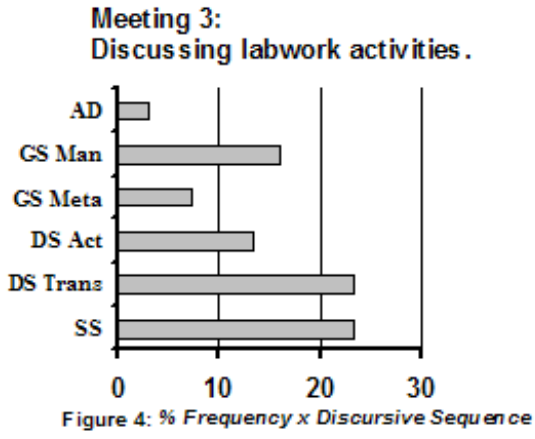


Figure 4: % *Frequency x Discursive Sequence*

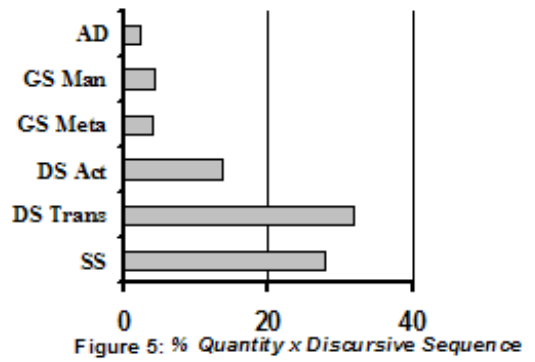


Figure 5: % *Quantity x Discursive Sequence*

The discussion of results that could follow is very rich. We show here only an example. If we look for the categories more frequent, we see that in both meetings teachers' discourse was many times about Scientific and Didactical issues, specially on Transposition. If now we look at the quantity histogram, them we can see that the situation differs a lot between the two meetings. Meeting 1 has very little discourse about scientific issues in comparison with discussion on the teaching of these issues. Meeting 3, on the contrary, has the same quantity of both types of discourse, being the most relevant in the meeting (aprox. 65% of discourse in the meeting belong to these categories). If now we look at the TCG's (Figures 6,7), meeting 1 is rather chaotic, with predominance of Transposition discourse. By contrast, meeting 3 shows trends of

regularity between both Didactical features of Transposition / design of students' Activities and Scientific discourse. This shows us that in this meeting teachers were continuously referring to their scientific knowledge in their discussion about the design of materials.

If we compare these observations with the Activity Segments, we see that meeting 1 was one of teachers' first meetings in which, without a concrete task, teachers were broadly discussing the content of the materials to develop. Meeting 3 was more task-oriented: teachers were designing practical work activities. This activity challenged teachers' knowledge of science, making them to focus their discourse on scientific issues.

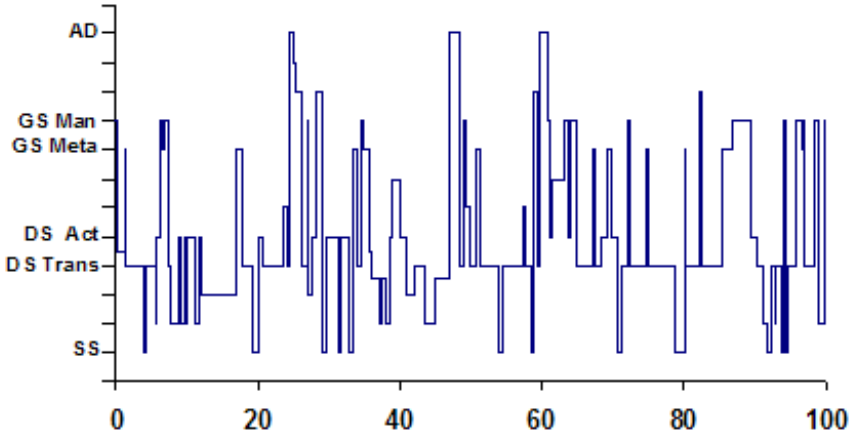


Figure 6: *Evolution of quantity of teachers' discourse along Meeting 1*

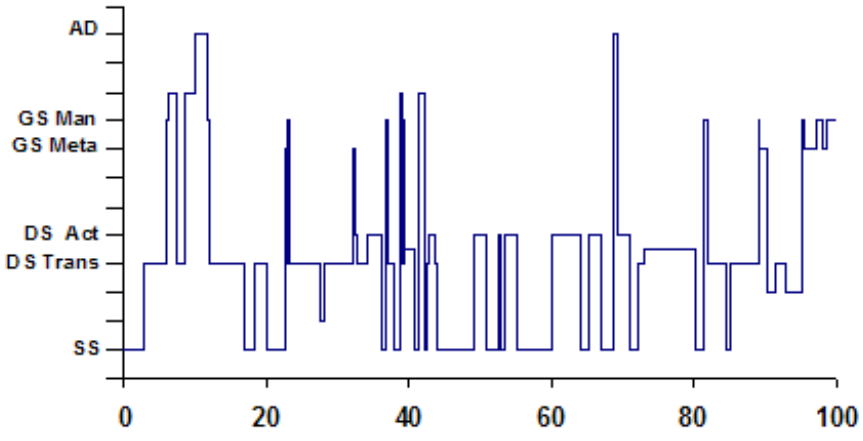


Figure 7: *Evolution of quantity of teachers' discourse along Meeting 2*

Conclusions and Implications

The analysis of teachers' discourse in cooperative-working environments allows us to identify content categories (semiotic spaces and discursive sequences) of this

discourse, i.e., what do teachers speak about in these situations. The amount, frequency and evolution of these discursive categories, when compared with the actual activities and materials teachers were doing in the meetings, give us interesting information for the teacher development field. For instance, in the discussion of results is shown that the designing of practical work by science specialists' teachers in different disciplines has been useful to promote teachers' sharing of their understandings of scientific concepts.

We have also methodological conclusions of this exploratory study. The new tools designed and used (Histograms and TCG's) are very useful in the sense that provide a "discursive picture" of the meetings that allow easy comparison among different kinds of meetings. Even though they cannot be used by themselves (for instance, cross-triangulation with a case-study of the teachers' group will give validity to the interpretations), they facilitate communication and comparison, both difficult in qualitative analysis.

Bibliography

CALSAMIBLIA, E. et. al. (1997). *La parla com a espectacle. Estudi d'un debat televisiu*. Cercle d'Anàlisi del Discurs. Barcelona.

COCHRAN-SMITH, M. & LYTLE S. (1999). Relationships of knowledge and practice: teacher learning in communities. En A. Iran-Nejad, & P. D. Pearson, P. D., (Eds*). Review of Research in Education.*, Washington DC: AERA, p. 249-305

CHEVALLARD, Y. (1985). *La Transposition Didactique*. Grenoble: La Pensée Sauvage.

HARGREAVES, D. (1999). The knowledge creating school. *British Journal of Educational Studies*. 47 (2), p.122-144

GROSSMAN, P., WINEBURG, S., & WOOLWORTH, S. (2001). Toward a Theory of Teacher Community . *Teachers College Record*. 103 (6), p. 942-1012

STODOLSKY, S.S. (1988). *The Subject Matters. Classroom Activity in Math and Social Studies*. Chicago: Chicago Press.

WILSON, S. M., & BERNE, J. (1999) Teacher learning and the acquisition of professional knowledge: an examination of research on contemporary professional development. En A. Iran-Nejad & P. D. Pearson, (Eds), *Review of Research in Education. AERA*. Washington DC, p. 173-209.

Abstract

This research examines the relationship between educational innovation and professional development in Science Education, arguing that when teachers play an active role in innovation, these scenarios become professional development scenarios themselves.

From a literature analysis of the field, characteristics of effective professional development are found according to a situated and socio-constructivist view of teacher learning. From this analysis, a model of ongoing and systemic professional development within a *new* school and professional culture is developed. This model stresses the importance of a focus on the subject, participation in authentic cooperation, and an inquiry/reflective stance from teachers sharing the common goal of fostering students', but also their own, learning.

The empirical part of this thesis includes the published reports of three different pieces of research undertaken in a variety of scenarios of implementation of innovations in science education in Catalonia. These contexts cover a rich spectrum: from top-down, short-term and research-based teacher training proposals to bottom-up, on-going, curriculum development initiatives. Both the shortcomings and positive outcomes of these scenarios are analysed concerning what professional development process teachers experience within them, reinforcing the aforementioned theoretical model with empirical evidence. Methodologically, the research uses different techniques for the analysis of language data, which are both Qualitative and Quantitative Content Analysis and Discourse Analysis. Data come from a variety of sources: video-tapes of lessons, video and audio tapes of teachers' meetings, teachers' semi-structured interviews, open questionnaires and teachers' curriculum documents. Some instruments for Quantitative Content Analysis are developed.

The implications of the research work are twofold. A *new* model of professional development in which this process is intertwined with school-based reform and innovation in which teachers play an active role is proposed. In addition, the research offers some methodological tools regarding the analysis of teachers' cooperative discourse.

The published papers that form part of this PhD dissertation are:

1. Pintó, R., Couso, D., Gutiérrez, R. (2005) Using Research on Teachers' Transformations of Innovations to Inform Teacher Education. The Case of Energy Degradation. *Science Education*, 89 (1), pp. 38-55.
2. Couso, D., Pintó, R. (2007) Teachers' Collaborative Reflections about School-Based Science Innovation in Spain. In Lang, M., Couso, D., Elster, D., Mooney-Simmie, G., Klinger, U. & Szybek, P. (Eds) *Professional Development and School Improvement*. Chapter 3, pp. 75-118. Studienverlag: Wien.
3. Couso, D., Pintó, R. (accepted, *in press*) Análisis del Contenido del Discurso Cooperativo de los Profesores de Ciencias en Contextos de Innovación Didáctica. *Enseñanza de la Ciencias,* ICE-UAB: Barcelona.

The main body of this dissertation is written in English. The publications that form part of this work are added in their original language, either English or Spanish.

UAB
Universitat Autònoma de Barcelona