A teacher's professional development
Training for a different kind of experimental work

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SUMMARY

The article includes part of a research study on experimental work in teaching science (Santos, 2002): a teacher with ten years in the profession received teacher training. It goes on to describe the training programme, which lasted six months and is included in the practice-oriented training paradigm (Kennedy, 1987), along with a reflective approach to practice (Gómez, 1992). The goal of this training was the teacher's professional development. The article also includes the teacher's own reflections, immediately after completing training and four years later.

Key words
Educational research, secondary education, teacher training, training programme, in-service training, practical skill

The training of science teachers in Portugal

In Portugal, teacher training may be divided into the following phases: initial training, training in the work context during the period of initiation into the profession (traineeship/practice period) and professional development (Garcia, 1999). Obviously, this third phase is intimately connected with lifelong learning, part of which is continuing vocational training in the shape of formal courses.

At the moment, a science teacher in Portugal receives initial training at a university (five years - four years plus one) or an institute of higher edu-

cation (four years, three years plus one). Universities train teachers for any level of education. Graduates of institutes of higher education, which are polytechnics, are only able to teach at pre-school, first primary school level (ages six to nine) and second primary school level (ages from 10 to 12).

A number of bodies are accredited to conduct formal courses of continuing vocational training. These are the universities, school training centres, scientific associations and teachers' associations, trade unions and firms. There is a very wide range of training on offer, from workshops (50-60 hours) and courses (at least 25 hours) of either the personal attendance or distance learning type, to the conduct of research projects. In Portugal, the continuing vocational training of teachers is one of the requirements for advancing in one's career. Advancement is connected with the policy of teacher assessment, which is made up of three elements: a critical reflection document prepared by the teacher under assessment, compulsory attendance at continuing vocational training courses and a verdict on the part of an assessment committee belonging to the school where the teacher works.

In a study on the implementation of teacher assessment policy in Portugal, it was concluded that the assessment policy, which is supposed to promote teachers' professional development and organisational improvements in schools, failed to include a number of characteristics which literature on the subject deems fundamental for attaining these goals. Implementing the teacher assessment system aims above all at the administrative goal of making it possible for a teacher to advance up the career ladder (Curado, 2002). In another study, (Marques *et al.*, printing) where teachers at the 'Mestre' (Master) grade were interviewed, and which identified obstacles to the links between research and educational practice in scientific education difficult, teachers said that initial training was inadequate and knowledge acquisition in continuing vocational training fell short, both in terms of education research and of specific fields. There is not enough training on offer in subjects of particular importance to teachers, such as experimental work, problem-solving, information and communication technologies and the use of existing resources in the school. It was also pointed out that initial and continuing vocational training used methods that were based mostly on passing on information and technical skills; the honing of social and self-training skills was neglected. As Garcia (2002) states, 'the ways in which teachers learn do not generally coincide with the possibilities offered by training institutions'.' (p. 27). Moreover, studies conducted in Portugal and cited by Flores and Shiroma (2003) provide evidence that in-service training was planned and implemented in accordance with a bureaucratic concept of technological orientation (Ferreira, 1994; Barroso & Canário, 1999; Ruela, 1999; Silva 2001), where empirical evidence demonstrated that continuing vocational training activities were planned and implemented in accordance with a bureaucratic concept orientated towards technology (Ferreira, 1994; Barroso & Canario, 1999; Ruela, 1999; Silva, 2001).

In the article '*A Formação de Professores em Portugal e a Universidade*' (Teacher training in Portugal and at university), Pereira (2002) asserts that *the problem is that teacher training at Portuguese universities, or even outside them, is that it is based on models (...) originally designed for accelerated teacher training; these fulfilled their historical functions in the 70s, when the aim was to render teaching more democratic but are entirely unsuited to current circumstances (…) as they fail to prepare teachers for the world in which they will be teaching for the next thirty years (…), and they do not dwell in the slightest upon lifelong learning, on learning to learn or on initiation into research.*' (p. 59).

Professional development of science teachers
A brief theoretical discussion

Below are a few definitions of professional development for teachers (PDT).
'*A process designed for the personal and professional development of individuals in an organisational climate of respect, positivism and support, the ultimate goal of which is to improve learning by pupils and continuing and responsible self-renewal on the part of educators and schools.*' (Dillon-Petersen, 1981, cited by Garcia, 1999)
'*The process which improves the knowledge, skills or attitudes of teachers*' (Sparks and Loucks-Horsley, 1990, pp. 234 and 235);
'*Professional development is more than just a stage in acquiring information; it means adjusting to change with the aim of modifying teaching practice, changing teachers' attitudes and improving pupils' performance. The professional development of a teacher is concerned with personal, vocational and organisational needs.*' (Heidman, 1990, cited by Garcia, 1999);
'*Professional development has been defined more broadly as including any activity or process that leads to better skills and attitudes. Understanding or action in current or future roles.*' (Fullan, 1990, cited by Garcia, 1999).
As may be seen, the concept of PDT includes many different dimensions, including pedagogical development, self-knowledge and self-understanding, cognitive development and theoretical development (Howey, 1985).
Professional development is a concept whereby the teacher is viewed as an educational professional who is constantly evolving as a person, as a professional and as an individual; and whereby teaching is viewed, not as an applied science, but rather as a deliberating practical activity with a clear-cut ethical component. From this point of view, professional development is seen as the combination of processes and strategies which make it easier for teachers to reflect upon their own practices; it allows them to manage practical and strategic knowledge while inducing them to learn from experience (Garcia, 1999). Here we can see the concept of reflection and the work of authors such as Schön (1983, 1990) and Zeichner (1987),

which centres on the process of training in the reflective analysis of the teacher's professional practice. Nevertheless, as Cachapuz et al. state (2002), it is also necessary to be acquainted in depth with what one is teaching and to hone one's own (particularly metacognitive) skills which such reflection demands. On the subject of initial teacher training, Pombo (1993) contends that, in addition to the scientific and pedagogical component, the reflective component, in which the teacher tries to create critical distance and overall integration of the various components, is necessary. When we talk about science teaching we have to refer to society as it is now, and in which constant cultural, scientific and technological changes are taking place; hence the need to prepare pupils for that society. Every teacher and every school has the duty to participate in their pupils' scientific training. Schools must realise that they too need to change.

When we talk about teaching science we have to talk about experimental work. The experimental dimension is fundamental to any science curriculum (Cachapuz *et al.* 2002). We need to ask ourselves whether it is important to change our educational practices in relation to experimental work in secondary education. The answer, most definitely, is yes. The pupils we are talking about are between 16 and 18, '*at an age when they need activities that provide them with a certain degree of autonomy and responsibility, that give them a challenge, that give them the taste for a scientific career, that help them to develop overall in both the personal and socio-occupational field.*' (Santos, 2002, p. 176). It is not certain that this is possible with routine experimental work. All science teachers must be made to conduct experimental work with their pupils, with recourse to the diversity of possible formats and without limiting themselves to using pre-established procedures which pupils follow step by step as if they were using cooking recipes. Research is one of the formats most widely upheld by a number of authors, on account of its potential for learning about science and learning in general. In investigative experimental work, pupils take on board and recognise the problem under study as something real and they are allowed to take a hand in the planning, execution, interpretation and assessment of the evidence and possible solutions, as well as communicating their results verbally and in writing (Lock, 1990). Hence, just as there is a change in the teacher's role, in which the core of the action takes place via the pupil, so training in experimental work is essential for the science teacher's professional development.

The training of science teachers conceived of as professional development has recently become relevant in research into science teaching. The professional development of teachers may be viewed as a general restructuring of the beliefs, attitudes and behaviour of teachers vis-à-vis science and scientific education (change in teaching) (Furio, C. and Carnicer, J., 2002).

The central idea of this kind of professional development for teachers is that the process is one of ongoing and inevitable learning. It is said that training programmes have to change before teachers can change; pro-

grammes must allow teachers to become active learners, who configure their professional development by reflecting on their own programme and practice (Clarke and Hollingsworth, 2002). The concept of ongoing and life-long professional learning is of fundamental importance.

Some results of an empirical study

In this study, part of an investigation into experimental work on teaching science (Santos, 2002) is set out, which involved training in pedagogy for a science teacher employed in secondary education, within the regular educational system. The points of departure were as follows: what type of training does one choose in order to induce the teacher to put into practice, together with her pupils, research experimental work, a method of teaching rarely used in science classrooms, [and] what strategy should be used to foster such a change in her teaching method?

At this point, we describe the teacher's standard practice, the professional development strategy and reflections thereon at two different points in time – namely, after the training process and four years after the experiment.

The teacher's standard practice

In order to gain a clear idea of the type of experimental work which this teacher was accustomed to allow her pupils to carry out in the classroom, we analysed the data collected in the course of an interview with the teacher conducted at the start of the study. In the interview, when we asked her how she taught her classes when it was necessary to put into practice experimental work and which support materials she used, the teacher replied as follows:

'What we do is provide some theoretical knowledge and on the basis of this proceed further in delving into a given problem. Because we provide the pupils with the protocols, we lead them to specific answers. They already know what the material is, and what method and procedure will be followed … So all they have to do is to carry out the experiment, assemble the results and try to draw some conclusions. Very often even the conclusions themselves are guided, because it is we who arrange the discussions in the record. It's all guided. We just spoon-feed them everything."

(⁴) These are Algeria, Egypt, Israel, Jordan, Lebanon, Morocco, the Palestinian Authorities, Syria and Tunisia.

(⁵) The Global Business Environment Ranking, which covers 60 countries and uses a range of indicators to evaluate the business environment, gives Syria a very poor rating, according to the Investor Roadmap for Syria (Syrian-European Business Centre).

The pupils did not participate in drawing up the research plan. They did not choose the problem, nor did they formulate the hypotheses or plan the experiment. There was no interpretation of mistakes either, with a single response being sought, confirming a theory and not explaining the phenomena or establishing a link between theory and practice. The pupils themselves and their teacher confirmed that this was the *modus operandi*. It fits in with a number of studies carried out in Portugal (Cachapuz *et al.*, 1989; Miguéns, 1990; Almeida, 1995; Silva, 1999 and Valente, 1999).

The process of training the teacher

We have just seen, as set out in the foregoing paragraph, that the teacher always used the same type of experimental work in her classes. Nevertheless, this can take various forms, one of them being research. In the same interview, at the beginning of the study, when asked about her research experimental work, the teacher said *'yes, I have heard about that but I do not know very much about it'* (…).*'I don't know of any colleague or teacher who has done this up to now, and I do have quite a few years' service behind me.'*

Arising from her training need were fresh questions about research, such as how to train a teacher and what model was to be used.

When training teachers, there are a number of different angles: *'Every direction taken stresses different aspects* (…) *none offers a complete model as a guide as to the implementation of a programme'* (Feiman-Nemser, 1990 p. 227). Bearing in mind our objective of allowing the teacher to develop professional skills in such a way that she is able to put into practice a new teaching/learning strategy, we drew up a training programme which is included in practical guidance and which, according to Kennedy (1990), entails deliberative action and critical analysis. Gómez divides this guidance into two approaches, one traditional and the other reflecting on practice. The process followed is included in the latter approach. Garcia (1999) affirms that, in teacher training, this guidance is basically used when organising and developing teaching practices. The process of training the teacher who took part in the study lasted six months and included the following activities:

1. An initial interview with the teacher. This was semi-structured and designed to learn about her teaching practice and how much theory she knew about experimental research.
2. Informal discussions between the researcher and the teacher that served to promote awareness and also acquaintance with the existence of various types of experimental work.
3. Reading and analysis of literature referring to the role of experimental work in teaching science.

(⁶) According to Emerging Syria 2005, Oxford Business Group.

4. Joint, retrospective reflection between the researcher and teacher on relating theory and practice, while acquainting the teacher with the way of guiding the research carried out by her pupils.
5. Looking at self, in a different group from that of the main study, in terms of the direction that experimental research work in the laboratory should follow.
6. The conduct of experimental work in a sequence of three investigations. It should be said that these classes were recorded and observed by the researcher without participation on her part.
7. Semi-structured interviews by the researcher with the teacher at the close of each investigation to ascertain her views on the results obtained and the way the whole process had taken place. The interview held after the third investigation aimed at further goals, namely assessing the extent to which the objectives initially proposed had been reached, and assessing the training impact of the study on the teacher's practices.

In these last interviews, the teacher pointed to the varied potential of this type of experimental work, developing the pupils' capacity to learn how to learn and also significant learning in terms of content and concepts, as we can infer from the following extracts:

'The capacity to learn how to learn - which is what they achieved by this entire process (...) *shows that beyond the knowledge we can transmit [to pupils], they should become able to use specific tools in order to 'learn to learn'- that's what is important here.'*

'Being able to set out a problem, hypothesise, plan the experiment, execute and analyse the results and draw conclusions - all these are important steps and constitute tools for effective learning. It therefore gives them the opportunity to transform all the information available to them into knowledge. Doing exactly this and knowing above all how to solve problems, not only in biology, but in one's future life (…) And what is it that is needed for this? They need to know how to choose (…), organise and relate - how to think. And it is this which, essentially, we have to teach them'

'On the basis of the research sequence they become able to orient (…) their reasoning and experience in such a way as to be able to grasp theoretical concepts.'

Concerning her own role in guiding and implementing experimental research, the teacher said that she felt a degree of uncertainty. She understood that in this kind of teaching/learning strategy, the teacher had also to be prepared to place herself in a position of learning. She went on to say that teachers and the school had to change the way in which they taught their pupils in order to better prepare them for life – by developing their ability to solve problems. The following extracts confirm these conclusions.

'To have the courage to propose open research [to the pupils] is a very great risk (…) on the one hand we do not know what it is they would like to do research into - to my mind, we feel afraid. I am afraid I shall not be up to it when it comes to answering their questions (…) if a pupil

notices any gaps in knowledge on the part of the teacher, this may lead to a credibility gap.'

'The other thing which can happen when we propose open research is an inversion of the teacher's role. In other words, the teacher is not only the person who, from the loftiness of his/her unquestionable erudition, is there to give out material. He/she has to be a person prepared to sit down beside the pupils in order to learn something as well (…). He/she does not stop teaching, but has to be of a disposition always to learn something (…). I think this is what I felt most deep down and it was this which made me think that this whole process boiled down to being in the right frame of mind for learning. After all, it is no crime not to know everything - the crime is not to want to learn more, is it not? Because the teacher will always have doubts and fears and have minor or major failings, is that not so?'

And she concluded that *'in the midst of all this, only one thing is certain:* "It is that one never knows everything".' This was something I felt deep down in myself when dealing with the children (…) One never knows everything and one always has to keep plodding along, updating one's knowledge all the time.'

After the three experimental investigations were completed by the pupils, the teacher reflected critically on her own practice. In talking about laboratory work that always used a set procedure, she said the pupils simply committed the content to memory to fit the final assessment and that *'once the national examinations are over, they forget about it.'* According to the teacher, what happens in the classrooms is that *'we get rid of all the content without further ado and, at bottom, it is not that which interests us.'* And again, on the subject of a critical attitude, the teacher continued:

'I had never thought of things this way and this whole process (…) actually made me aware of these [issues]. The truth is that as teachers we have not quite come up to scratch. Or else it is the way in which we communicate with our charges. We have to reformulate the whole system of teaching, because it really does have to be different, they have to be given the opportunity to learn to disentangle their problems and find solutions to the problems life throws at them and we are not going to achieve this by dishing out subject matter. To do this we really do need to proceed differently.'

What the teacher thought

After four years of training, the same teacher told us there had been a change in her teaching practice. She told us that, currently, and in the course of the last four years, she had allowed her pupils to suggest research that interested them. The following examples illustrate this:

'On the basis of the training, in my presentation classes, I always say "you are entirely free to propose any subject for research you like" (…).

After that, I only help in collection and selection, they do the project and I see whether it has been well done or not (…) And from then on, they do the work and they research the conclusions.'

'I remember a research project we carried out after our experiment. In it, the pupils were putting into practice the principles of asexual reproduction for the propagation of a pineapple. Such a thing had never entered my head - it had never been catered for in any syllabus (…). It brought with it the need for all kinds of knowledge. When the goals had been defined, information had to be obtained about temperature conditions (…). Obviously the pineapple (laughter) had to spend the whole winter being kept warm and the heater was on day and night, but in the end we managed to propagate it. But the process took the whole year (…). These were things I did not know about and it [the pupils] who actually did it. They learned how to learn in their own way. If they had any doubt, they coped with it (…). I found the exercise very useful because at the end of the day they learned how to learn.'

In the course of the same interview, it was reaffirmed that investigative experimental work had an impact on pupils' learning. Once again she mentioned learning how to learn and the understanding of the syllabus which, in her view, the pupils will never forget (i.e. they learned things which meant something to them). She added that the pupils showed greater commitment and motivation than previously in carrying out these activities.

'What is the advantage of this?(…) These research projects, besides adding to the pupils' store of knowledge, increased their wisdom. To me, the advantage is that they learned how to learn for themselves. And it is this proficiency that is going to enable them to survive through life. Because, throughout their lives, they are going to have to adjust (…). We have to think about preparing the pupils to become flexible and adaptable. What I achieved in implementing this research project was, at bottom, enabling pupil to learn for themselves (…) they have to have a space in which to learn how to learn and adjust to different situations, because it is just this that is going to enable them to be lifelong learners.'

'When they have that freedom to explore the research subject, when it is they who propose the subject, collect the material and prepare the whole scenario, some of them will show commitment (…) There are pupils we sometimes label disinterested and then, when they are given the opportunity to be in charge of operations, they are fantastic, they are workers, they learn everything expected of them – sometimes more.'

The answer to the question 'What did you change as a teacher?' enabled us to see that she changed her beliefs and attitudes. 'By then, I began viewing the pupils in a different light. *All pupils are different individuals, learning in different ways and we have to apply different strategies, otherwise, you will not get through to all of them.'* She went on to explain that *'there are pupils who succeed very well in learning what we put to them*

by memorising, by reading, by working through exercises, but there are others who do not. There are others who need to do and touch.' Out of this comes an attitude of respect for the person who every pupil is. '*I give them autonomy but (…) there are some who receive it with open arms and are motivated and intend to undertake research, and there are others who will not (…). People are different and we have got to respect this.'*

Beyond these changed concepts with regard to pupils, she again says, just as she did four years ago, that *'they have started having a dialogue with me. I am learning a lot with them.'* Their view of the teacher changed also, hence she is not seen as the fount of all wisdom and is final arbiter of learning for her pupils.

> *'I cannot impose on a whole class just one way of doing things. This would show disrespect towards those who do not like it and who do not learn in this way (…). Because if I do not manage to help them to learn what I would like them to learn, whose fault is it? Mine.(…) Because I did not have the ability to see that they were different and had different ways of learning(…). You just have to vary your strategies. At the end of the day, you are forced to perceive that there are pupils who are different from the others. They are persons (…) they manage to interpret things in a way that another does not. Clearly, human beings are different. They have many facets, not just in the way they learn and we have to use different approaches.'*

Nevertheless, having changed her practice with regard to experimental teaching, the teacher pointed to constraints on a change in practice, namely large classes, the Ministry's syllabus and guidelines, the manuals adopted and also the fact that the pupils were unaccustomed to participating in strategies of this kind. The methodological suggestions for programmes for the various disciplines included in the Education Ministry's guidelines (1991) refer to few experiment-based activities, none of a research nature.

Again, we would like to mention what the science teacher had to say about the training process. For her, the most important thing was the effect that this type of work had upon her pupils. She stated that *'what was most gratifying for me was to see the satisfaction on the children's faces through having the freedom to plan things their way.'* She went on *'it was also important to know that other methods are available – in our own initial training we learned nothing of all this. We have to get up to date, and it was good to know that other methods existed.'* A third aspect she said had been important in this training was always having been accompanied by the researcher/trainer. According to the teacher, *'I would never have dared to try it out on my own – even though I read in a book that there is such a thing as open research. It took some effort to get out of my inertia in order to explore that avenue. Yet I did feel stimulated.'*

She also said looking at oneself was an important part of the training process. *'We looked at ourselves and you explained to me how it is that things worked. I was jogging along very nicely – the next year I really stepped up the pace.'*

Conclusion

We have seen in the study we presented that after the training course, the teacher involved changed her way of teaching with experiments. Her thoughts, which we set out, were expressed shortly after the training course and four years after the actual study. They refer to changes in her teaching practice, in the results of learning on the part of her pupils and in her beliefs and attitudes – in line with the model for teacher change (Guskey, 1986), which shows the process of change over time. Thus, starting out from the training programme that targeted the professional development of the teacher (as explained in 3b) above), changes in her teaching practice took place, which influenced how the pupils learned. In turn, because results were positive, the changes in practice contributed towards changing the teacher's beliefs and attitudes.

Shortly after the three orientation sessions on research-based experimental work, the teacher called her own teaching practice into question and showed a critical attitude and a need for change in teacher's practices and in education in general. The teacher understood the need to have an attitude embracing permanent training and learning – of being a 'lifelong pupil.' '*By seeing teachers as pupils who continuously build up their own knowledge of science and pedagogy, teacher training can become an activity that supports teachers in the construction and reconstruction of knowledge structures concerning teaching and learning*' (Dana *et al.*, 1998, p. 120). Or, as Pombo (1993) put it, '*what better training is there for a teacher than his/her awareness of being an eternal pupil?*'

The question we have to ask is: 'why did the teacher change her teaching practice?' A number of factors were equally important in influencing this change. There was the fact that training took place in the work environment, this being seen as the best place for further training for teachers (Kincheloe, 1989 and Pérez 1988, cited by Garcia, 1999), or, as Zeichner (1987) contended: '*practical experiments in schools do, of necessity, contribute towards training better teachers.*' (p. 39).

Another important factor was the thinking process taking place at different times. Time was made available for reflection throughout the training process. The reading and analysis of the literature supplied and the interviews with the teacher fostered in her, and indeed allowed her, thoughtful analysis of her professional practice (this fits in with the continuing vocational training models for teachers in which the teacher is seen as a thinking professional, which presupposes that '*the process of understanding and improving (a teacher's) teaching must start with thinking about his/her own experience.*' (Zeichner, 1993, p. 17). This reflecting analysis showed the teacher that there were other possible practices as regards experimental teaching, inspiring in her a wish to improve and therefore to change. Resorting to self-examination encouraged reflection – being able to see oneself in action and reflecting on the action.

The process of looking at oneself, the recording of lessons and the accompaniment by the researcher were collectively factors which, by allowing feedback, fostered reflection, providing help as regards what to change and how to bring it about (in this particular instance, the skills necessary for preparing and carrying out research-based experimental work).

Reflecting on action was a constant in the whole process. '*Reflecting on action and on reflection-in-action (critical reflection according to Habermas) [which] can be regarded as retrospective analysis by the individual of the characteristics and processes of his/her own action (…) In reflection on action, the practical professional, liberated from the conditions governing the practical situation, can apply the conceptual tools and strategies for analysis in the direction of understanding and reconstructing his or her practice*' (Gómez, 1992, p. 105).

We know that the factors which can help the teacher to become more involved in implementing innovation, and consequently his or her professional development, are: access to information on the innovations he/she is going to be involved in and awareness of innovations of interest to the teacher (Fullan, 1991; Furio & Carnicer, 2002). We gave the teacher literature on the role of experiments in the teaching of science. This link between theory and practice during the training process was important since '*grounding teaching practices on an understanding guided by theory can become an important component of lifelong learning which is the teacher's effort to improve his/her teaching practices*. (Dana *et al.*, 1998, p. 120).

In addition to the training programme, the teacher's personal epistemological attitudes are important (Furio & Carnicer, 2002). By this we mean the teacher's interest as a factor which can foster a change in practice (Fullan, 1991). In this sense, the teacher involved in the study also referred to the teacher's intrinsic motivation as a factor to set beside support from the school. Among the factors favouring her own change in the classroom, she mentions the support received from the school's Board of Governors, particularly in connection with the purchase of equipment. And she adds '*when there is no equipment, you improvise.*' The teacher showed openness and a willingness to change. She herself mentions personal characteristics of teachers who can help in the process of change and innovation in education: '*having the spirit of openness and observation. Observing that there are pupils who can receive things well one way and others in another way. And then having common sense, perceiving what needs to be changed and having the willingness to change.*' She goes on to talk about courage. '*You have to have courage not only to accept that new methods exist but to try them out.*'

In addition to all the factors mentioned, the fact that the teacher observed that her pupils were learning more and developing scientific skills, as research went on, encouraged her in the long term to change her way of teaching experimental work.

These results lead us to ask: 'What inferences can be drawn for teacher training and, specifically, for continuing vocational training?' In our opinion,

training models must include certain strategies. As well as the teacher's intrinsic motivation, account must be taken of his/her interests and training needs. Training should be embedded in practice. Teaching practice should be used as the source and site of learning, via reflection and inquiry, promoting a critical debate on conventional teaching and on other, more effective, possibilities for innovation in teaching (based on advances in science teaching). To this must be added the teacher's own access to information about innovation and his or her ability to actually implement innovative proposals in the classroom. In this way, theory and practice can be integrated and the teacher can develop a positive attitude towards innovation and research in teaching. Throughout this process there is a need for theoretical and tutorial backup. Ponte *et al.* (2004) cite Riedel (1977), who speaks of the need for facilitators who can help teachers develop professional knowledge via practice.

Another aspect to be considered in the training programme is support from the school as an institution. The idea of a learning teacher and of the school as a learning community is important (Clarke and Hollingsworth, 2002). It is also crucial to create and maintain an effective partnership between schools and institutes of higher education. This is an important link if we are to build communities of teachers as lifelong learners, in recognition of the ability of these institutions to (re)construct various types of knowledge.

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