TOWARDS A PROPOSAL FOR EFFECTIVE ONGOING TRAINING PROGRAMMES FOR SCIENCE TEACHERS

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Abstract

This paper begins by demonstrating the need to enhance the training of people who currently active teachers and presents a proposal of ongoing training programme founded in the results of science education research. To begin with, a critical analysis about some of the dominant models of teacher training in which exist a lack of integration between theory and practice is carried out. Next, the hypothesis that the effective formation programs are those that have as objective to facilitate the teacher's immersion in the investigation and innovation in science education is developed. In addition, in this programs a group of constructivism based strategies that initiates the teacher in the investigation of the problems that are presented in the classroom have been used. Finally, the existence of investigation or innovation consolidated groups in which new teachers could be trained as investigators, or to promote the formation of teacher's teams that work in the problems of the educational practice is also required.
Key words: *teacher professional development, in-service science teacher training, analysis of models in science teacher education, strategies for effective programmes.*

Introduction

The beginning of this 21st century is highly interesting from a socio-educational perspective. Government education officials in many countries such as the United Kingdom, the United States, Spain, Chile, Argentina and Mexico aim to reform the science education curriculum and promote research into science teaching. Science education is now seen to be not only a long term investment, but also an essential factor in short term development (Gil et al., 1998).

There is increasing talk of the need to include a science curriculum in the obligatory stage of education (up to 15 or 16 years of age) aimed at teaching scientific technological literacy. This literacy implies accepting that students must learn scientific and technological knowledge, the processes that can help these constructions and acquire a critical interest in regard to the role science and technology play in their lives. Such knowledge, skills, abilities and attitudes must make it possible for citizens to carry out well grounded evaluations and take sound decisions in reference to problems linked to scientific and technological development.

The trends observed in the curriculum presented in a publication by the National Research Council (1996) entitled National Science Education Standards are heading in this direction as a project for a new way of teaching science in the 21st century. They point out that: "In a world filled with the products of scientific inquiry, scientific literacy has become a necessity for everyone." Furthermore, the World Conference on Science for the 21st Century held in June 1999 by UNESCO and the International Council for Science (ICSU) call for moves in this direction. The Programme Project

(Budapest Declaration, 1999) highlights the need to provide everyone with basic science education and presents the steps to be taken by governments in order to accomplish the objectives proposed. These changes in science education share the same goals as those established in the field of STES (science, technology, environment and society) interactions, which are aimed at bringing an end to the decontextualised vision of science and scientific activity to which science teaching contributes by presenting elaborate knowledge that ignores the social, historical and ethical problems that are the bounds of scientific development (Solbes and Vilches, 1997; Solbes and Traver, 2003).

However, education in general and science in particular cannot be improved by isolated actions. Systematic effort is required (including significant economic investment in infrastructure, materials, new centres, well-trained teachers, etc.) in order for the education system to converge with the ultimate goal of enhancing education quality. In order to achieve this, the results of education research and innovation must be taken into account. It is no surprise, for example, that in 1996 the US National Research Council declared education research in the fields of science, mathematics and engineering one of the eight primary strategic areas to invest human and material resources. In this study, there is widespread agreement that one of the factors that most improves the quality of education is teacher training. Research has highlighted the distance between the innovative curriculum planned by the designers and the curriculum that is actually taught by teachers (Cronin-Jones, 1991). This is why improving or changing science education also requires substantial changes in teacher epistemology. Such changes are not easy to make and we have already seen how teacher training based on isolated instructions regarding the new curriculum, no matter how interesting, is generally speaking ineffective. It is worth recording the comments made by Briscoe (1991, p. 185) to this extent: 'Each year as summer approaches, thousands of teachers participate in summer workshops or attend college classes with the intent of enhancing their professional development. When they return to their classrooms in the fall they believe themselves ready utilize new techniques, new curriculum materials, and new content knowledge in creative ways to enhance student learning. But many of these teachers, before they even realize what has happened, find themselves teaching in the same way they always have, utilizing some of the new materials, but adapting them to fit traditional patterns. By the end of the year teachers are frustrated and disappointed that nothing seemed to "work" and the students haven't performed on the average, any better than students in past years. What happened to all the new ideas that had earlier seemed so promising? Why hadn't things changed?'

This paper will be concerned precisely with that issue: the search for models of ongoing training that help to promote substantial changes in science teachers. This age-old problem once again deserves the attention of institutions such as the Organisation of Iberoamerican States for Education, Science and Culture (García-Sípido and Plaza, 1996). This work presents in the first place a brief critical analysis of some of the dominant models for teacher training in order to move on to reasoning an alternative ongoing training model.

Critical analysis of some of the most dominant models in science teacher training

We will begin by critically reviewing the theoretical models that science teacher training has been based on up to now in order to summarise their contributions and shortcomings.

First of all, two stereotypes must be criticised where teacher training is concerned, which can be considered two extremes of one continuum: the *innatist* and the *simple environmentalist stereotypes*. The former is based on an essentialist or vocationalist view of teacher training whereby being a good teacher is a question of personality, of having certain innate skills or of being somewhat idiosyncratic. One phrase that is often pronounced and defines this point of view well is "you are a good teacher or you are born one". The simple environmentalist can be considered to be at the other end of the continuum, according to which the profession is relativised and teaching is "assumed to be easy." In other words, all one needs to be a good teacher is to have a comprehensive knowledge of the conceptual contents, a bit of common sense and some experience (Gil, 1991; Furió, 1992). These views are quite widespread among teachers and academia authorities and there are several "versions" or forms, such as the professional or traditional approaches to teacher training (Zeichtner,

1987) whereby the future teacher must be considered an apprentice who, alongside an experienced teacher, will be able to learn how, through imitation or being given suitable indications, to be come a "good teacher".

Another mode of training that has received, and merited, a great deal of criticism on behalf of teacher training reconceptualists in general, as well as from those who defend the critical theory of teaching, is the so-called *'process-product'* model. According to this model, training must consist of teaching future or current teachers the skills and abilities that excellent teachers employ with effective results. This model ignores the fact that, as teaching research indicates, educators have beliefs, opinions, ideas, attitudes and behaviours that constitute what is known as *spontaneous teacher thinking, personal epistemology or implicit theories on science and science teaching,* among other labels. (Porlán and Martín, 2002). Personal epistemology as a model (often scorned by the label of 'traditional teaching') is a tacit body of teaching knowledge that guides professional know-how and which must be understood well if the intention is to transform it, as we will see in the next section.

This review of teacher training models cannot omit the approach that is currently dominant. We are referring to the *summative model*, which is based on the hypothesis that good teacher training is the result of a juxtaposition or sum of good scientific preparation on the one hand, and general psycho socio-pedagogical training on the other (Furió et al., 1992). This model is prototypical in the initial training of science teachers at North American universities and is also widely used in Iberoamerican countries, as can be appreciated in the analysis of these curricula included in the Ibercima project (Bermúdez et al., 1994). In relation to this model, it is worth mentioning the criticism on behalf of McDermott (1990) of both science and teacher training courses. In fact, this author states that the scientific preparation of teachers is addressed by the science departments that teach the same standard courses the University provides all students with, regardless of whether or not they are going to become educators. The curriculum of these courses is characterised by the following aspects:

- The length of the curriculum outweighs its depth and, therefore, very little time is spent teaching/studying the scientific concepts involved. This results in these concepts being taught superficially.
- Class format stimulates passive learning and makes future teachers accustomed to transmitting and receiving knowledge that has already been elaborated. As a result, in class experiences of other alternative means of teaching that are more compatible with knowledge building are not promoted.
- Solving standard problems leads to repetitive algorithmic methods and does not help to develop a future teacher's reasoning ability, which would enable them to tackle new situations such as, for example, the unexpected questions that students normally ask in class.
- Common laboratory practice involves the use of sophisticated equipment that, generally speaking, are not used in secondary science education. The method used is manipulating and, paradoxically, not very experimental at all in terms what is understood, from a current epistemological perspective, as scientific activity. That is, students must adhere to written instructions in a recipe-like script, which normally begins with the material and procedure to be followed. The essential aspects of scientific methodology, such as considering problems, inventing solutions in the form of hypotheses and creating experimental designs to verify them, are absent in this format.

As regards the objections the foregoing researcher made in relation to the teacher training courses, the following figured prominently:

- They are generally taught using a very similar strategy to that employed in science courses, that is, by means of transmitting pedagogical and teaching knowledge that has already been elaborated (teaching methodology can sometimes be so incoherent as to explain 'active class methods' by means of a dictation in class).
- These teaching strategies are presented in abstract terms. It is unlikely that (trainee or fully-qualified) teachers will know how to adapt them to their specific subject or to new situations.

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- Teaching methods are not studied in the domain in which they are to be employed. That is, they are not integrated into the subject or discipline the future educator must teach.

This omission of subject matter in training courses has also received criticism in pedagogical circles. In this sense, Shulman (1992) says that psycho pedagogues have studied many of the factors that could affect educational interaction in class, leaving the discipline itself out of the system under study, which is why this author draws people's attention to the omission in teaching of the *'lost paradigm'*. That is, there is a lack of integration between scientific matter and education courses.

The foregoing critical analysis of the prevailing models in teacher training lead us to turn our attention towards preparing a more rigorous preparation of teachers in order to make them capable of dealing with the specific problems that will arise while teaching science.

An effective teacher training programme should achieve full teacher immersion in education innovation and research

Simplistic views of teacher training are beginning to be questioned and people are beginning to understand the need for rigorous preparation in order to guarantee a quality education. The establishment of science education in the late 1980s as a body of knowledge that attempts *to solve the problems that arise in both formal and informal science education* (Aliberas et al., 1989; Furió, 1994a; Gil, 1996; Porlán, 1998; Hodson, 1992), implies that professional training must be aimed at a given field or discipline in order for specialised education to become the backbone of teacher education (Furió et al., 1992) in order to attain hypothetical solutions to the multiple problems involved in teaching. Furthermore, handbooks (Gabel, 1994; Fraser and Tobin, 1998; Perales and Cañal, 2000) and books that have been published in the field of science education (Duschl, 1990; Gil et al., 1991; Jiménez et al., 2003) ratify the widespread agreement over the problems the issues being discussed.

But having a body of teaching knowledge at one's disposal is not enough for teachers to participate in the renovation of education. It is necessary to take into account the research that has been carried out in this domain since the 1990s, which revealed the lack of attention paid to teacher participation in educational change and curricular reform. Generally speaking, curriculum designers are concerned with preparing materials for the educational reform and courses to disseminate them. Research reveals that such courses not at all effective in diffusing the new direction of the curriculum, as has been the case with the reform undertaken recently in Spain. As mentioned in the introduction, the United States has experienced a similar situation, as pointed out by Briscoe (1991) who says that thousands of teachers every year attend refresher courses or seminars with disappointing results. Why are such courses ineffective? Three causes indicated by researchers (Gil et al., 1998; Solbes et al., 2004) are referred to briefly below.

In the first place, as mentioned in the previous section, an education model is more than a set of juxtaposed and interchangeable elements: this framework coherent to a certain extent and each element is supported by the rest (Gil, 1991). Consequently, this explains why teacher training that is based on presenting isolated contributions that lack coherency are ineffective. In this sense, for example, researchers have drawn attention to the need to accompany curricular innovation with similar changes in evaluation (Linn, 1987). Indeed, the innovations or new objectives that have been introduced will have little impact if evaluation continues to involve exercises aimed at testing how well students remember certain concepts. Students will see this as the real objective of studying.

However, even if more far-reaching training programmes are presented in order to make it easier for teachers to become involved in the new direction of studies, we must bear in mind a second reason behind the ineffectiveness of such courses: curriculum designers do not take into account the influence of teachers' conceptions on the implementation of the new curriculum (Cronin-Jones, 1991). In fact, studying teachers' preconceived ideas has become a priority line of research, both in the field of science education (Gil et al., 1991; Hodson, 1993; Porlán and Martín, 2002; Mellado, 1998) and education in general.

The teaching world is beginning to realise that in order for new teaching knowledge to be absorbed entirely there must be a change in education where teachers' personal epistemology is concerned. Such a change in epistemology would involve abandoning the model of *environmental* *teacher education* acquired by in service teachers throughout prehistoric times, firstly as a student and later as a teacher. This epistemology can be assumed, in terms of a hypothesis, to be in line with the model of teaching/learning through verbal knowledge transmission. Instead, a model that is more coherent with respect to science education and more effective in solving the problems in this domain must be introduced. And this is where; in order to achieve the change mentioned above, we refer to the third cause that explains why teachers fail to become involved in educational reform: teachers' lack of ability to transmit the new proposals made by experts to be applied in the classroom. As Briscoe (1991) states, teachers must participate in the construction of new teaching knowledge by tackling the problems that education involves. In order for this to occur, teachers must be included in a process of curriculum research or innovation. This will also involve a gradual but ongoing change that will initially require more help and guidance until teachers acquire learn to think like researchers and directly assume their role as such (Carnicer and Furió, 2002). At this point and naturally, teachers will become 'permanent apprentices in the art of science education'.

In summary, the three causes referred to above are: forgetting that an educational model is a structure with some degree of coherency, not taking into account teachers' conceptions of science and science education and that teachers do not participate in the construction of new teaching knowledge.

The rigorous training required to prepare a teacher in science education means this process cannot be completed inside the initial period set aside for training, which must be brief and short. Furthermore, many of the problems that arise in education do not make sense until teachers have faced them in the course of their everyday work. This reinforces the idea that teacher training should be increasingly based on an ongoing training structure that must be a long process, or even better, spread more or less intermittently over teachers' entire working life (Carnicer et al., 1993)

For this reason, researchers such as Stenhouse (1975) proposed that teachers themselves needed to reflect upon their own teaching practices in order to improve them. Teachers now have a host of knowledge at their disposal in the form of research that can guide such reflection – knowledge related to alternative student conceptions and to conceptual change, problem solving, new approaches to practical work, spontaneous teacher thinking, etc, which has gradually and successfully become a part of the theoretical body of knowledge we call Science Education. It is logical for teachers to absorb this knowledge and use it to try and solve the problems that arise in their everyday work. That is, we must ensure that teachers themselves first study this theoretical body of knowledge to later be able to participate in building on it. In other words, teachers must become involved in education research (Solbes and Souto, 1997).

However, several researchers, such as Pekarek et al. (1996), mention various reasons why the results obtained from education research are not taken into account by primary and secondary school teachers: research results are too general to be used by teachers; papers do not address specific issues, in the sense of possible action and clear rather than ambiguous results; a lot of teachers still consider research irrelevant to their everyday teaching; researchers write more for the academic community than for teachers. Furthermore, primary and secondary school teacher working conditions not surprisingly discourage them from participating in research in science education (Solbes et al., 2004).

Some make things even more difficult by questioning the motto of Butzow and Gabel (1986) that we are defending: "a teacher, a researcher". They state that a primary or secondary school teacher's job is only to teach and that research corresponds to university lecturers/professors (Moreira, 1998). But what reasons or epistemological impediments prevent any primary, secondary school or university teacher from racing up to the challenges there everyday work involves? And why not try to do your job the best you can, which is by becoming immersed in education research and innovation? Consequently, the figure of a teacher/researcher must be the objective of ongoing training, a current of thought that has received recent support. Kyle et al. (1991, p. 413), on discussing the role of education research in science teaching say: "...A new image of the role of the teacher is emerging as well. In addition to possessing discipline-specific knowledge and knowledge about effective pedagogy, teachers must be afforded the time to share ideas with colleagues, participate in professional development, and inquire about teaching and learning. Teachers must be active, reflective practitioners who engage in constructing a curriculum to enhance the development of all students".

There is, therefore, a two-fold need to be taken into account in teacher research training derived from the points discussed above. On the one hand, in order for teachers to learn this education knowledge well, training strategies must be reconsidered in order to bring them in line with the education change being pursued. On the other hand, a sound ongoing training framework is required to carefully prepare teachers in the field of Science Education and research. These will be the two issues that will be addressed next. There are of course other aspects of this training that, in light of the limitations of this paper, will not be tackled, including selecting Science Education curriculum contents, but there is also literature that deals with this aspect and which can be consulted (Furió and Gil, 1989; Gil, 1991; Porlán, 1998).

Strategies that facilitate didactic change

As mentioned in the introduction, training strategies based on short courses in which verbal instructions are given to teachers regarding isolated aspects of their teaching are not effective. It is understandable how a change in part of such a complex structure as a teacher's personal epistemology is easily forgotten over time and why no profound didactical change occurs in the medium term. In the previous section, the conclusion was drawn that permanence training programmes must be redirected towards involving teachers in the research that tackles the problems that arise in teaching and learning. Hypothetically, only through encouraging teachers to take an investigative approach to the problems that arise in the classroom will they manage to improve their teaching skills and prospects of professional development (Furió y Carnicer, 2002). Supposing this is the case, the question boils down to how this didactic change can be achieved. That is, what training strategies could help teachers who are not even 'consumers' of research to take the step towards becoming 'producers of didactic knowledge?

Here is where we can consider the results obtained following more than 20 years of research into alternative student conceptions and conceptual, methodological and attitude change strategies and extrapolate them to spontaneous teacher thinking research in order to facilitate the didactic change indicated previously. In general, one hypothesis to be taken into account is that which will promote strategies that favour constructivist environments (Powell, 2003; Bain, 2004) in permanent teacher training. As indicated by Furió (1994a): 'The conditions of a constructivist programme are all those which facilitate the creation of a working climate identical to that which prevails in an effective scientific research team devoted to responding to or producing didactic innovations and research'. Indeed, teaching strategies such as those in the '*science education based on developing guided research*' (Furió, 1994b; Guisasola et al., 2008) or *'inquiry-based science education'* (Rocard et al., 2007) are achieving good results, not only among students, but also among teachers (Furió et al., 2003; Furió et al., 2000; Furió and Carnicer, 2002). Such strategies use the metaphor of trainee teachers as 'new researchers' who respond to the research that has already been carried out. Teachers work together in small groups led by an expert researcher with experience in the field.

Some of the conditions that ongoing training strategies should have in order to be effective and facilitate didactic change among teachers are:

a. The main objective of training programme must be to meet teachers' most immediate training needs. That is, the programme must be related to the problems that teacher involves. In order to achieve this, the programme must allow those attending, where possible, to become involved in establishing the objectives, or at least to acquire a preliminary idea of the thread of the programme (Gil et al., 1998).
   In this sense, *knowing teachers' ideas and interests in relation to ongoing professional training is vital* when it comes to building new didactic knowledge. For example, teachers who are in the early years of their career will need and be more interested in acquiring skills and abilities to be able to lead a class accordingly than those who have been teaching for longer (Furió and Carnicer, 2002).
b. The first elements to be included in an effective ongoing training programme must encourage teachers to *build a theoretical body of knowledge: that of Science Education*. Such elements must be coherent and integrated even if they are presented in several different units (Gunstone et al., 1993; Gil et al., 1991).

Training programmes that present isolated aspects of didactic knowledge or which are devoted to training isolated skills or abilities are of little use. One must bear in mind that the didactic change we pursue involves criticising a conceptual teaching framework (common teacher epistemology) and a qualitative leap to another framework that could be more useful in solving the problems that arise in science teaching and education. General pedagogical contents that are not applied in specific teaching contexts are also ineffective (McDermott, 1990; Feiman-Nemser, 1990).

c. Courses must be aimed at encouraging an *explicit didactic reflection* that questions the 'natural' character of what has always been done in the past. That is, we must question all spontaneous teacher reasoning, attitudes and behaviour that hinder the transformation of science teaching. By means of these critical reflections, teachers become aware of the problems faced in class, thus identifying both learning difficulties and teaching shortfalls (Furió and Gil, 1989; Tobin and Espinet, 1989; Barrow, 1991; Anderson and Mitchener, 1994).

d. One important aspect which helps teachers to make the didactic reflection described above and which is worth highlighting is that programme contents be covered by *discussing didactic problems collectively in small groups in an atmosphere of constructive cooperation and collaboration.* This exchange of information and experience, together with opinion sharing and expert researcher corrections are considered vital for teachers' professional enrichment (Gunstone et al., 1993; Furió, 1994a; Gil, 1996; Lijsen, 2000).

e. Training strategies must *encourage experience with well-founded innovation proposals that reveal the potential for transforming common teaching habits* and, above all, that show there are teaching methods that facilitate knowledge building and through which a significant amount of learning can take place (Duit et al., 2007).
An effective way of integrating theory and practical work in these training strategies is to make the teachers who are debating an innovation there and then experience similar learning situations to those they themselves will have to promote on using them in class (methodological isomorphism between ongoing training strategies and the innovation that will supposedly improve learning) (Furió and Gil, 1989, Parke and Coble, 1997; de Jong and van der Valk, 2007).

f. Finally, ongoing training programmes must be designed to encourage teachers to innovate and investigate into the didactic problems under consideration (Ratcliffe et al., 2005; Millar et al., 2006). This stage will be more complex and longer, as the aim is not only to involve teachers in (re)building Science Education knowledge, but also to help them to build independent work teams that, little by little, become a part of their corresponding community of researchers and innovators and thus help to produce new knowledge (de Jong and van der Valk, 2007).

Let us therefore move on to look into the obstacles that can prevent these independent teams of teachers from being formed and in what direction action should be taken to overcome them.

What training frameworks encourage teachers to become researchers or innovators?

As mentioned previously, an effective training programme, albeit long term, must aim for teachers to become involved in didactic research and innovation teams. Such teams may exist and must be supported, but if these were not the case, we have to find a way to create them in order for new teachers to join them. These teams will be a structural element of first order in ongoing teacher training.

Therefore, the question of what frameworks can provide effective training strategies can be generically answered as follows: 'all those that encourage collective self teaching'. The ideal situation would be for teams or groups to already exist and be able to incorporate new generations of teachers. These teams could teach new members in a functional manner by working together. However, in reality there are few independent teams of teachers involved in didactic research and there are many difficulties that prevent such groups from being created, among which the following are worthy of mention (Gil et al., 1998; Solbes, Furió et al., 2004):

- Science teachers have little experience in working in teams. Professional isolation is a prototypical working characteristic which today is predominant.

- Long working hours (large number of classes a day, class preparation, exams, class management, tutoring etc.) is a logistic obstacle that prevents secondary school teachers from meeting up with their colleagues in order to discuss their work in groups.
- Teachers' current working conditions in most countries do not generally include the need for ongoing professional training as an essential part of their job.

However, despite these obstacles, steps can be taken towards gradually promoting the goal of teacher self-training through forming teams of teachers. These steps must be aimed at helping to consolidate sound ongoing training framework in the long term in which teachers can discuss the problems involved in teaching Science. In order to achieve such a framework, these groups of teachers will obviously have to be coordinated, if possible, along with all the organisms involved in ongoing professional training (Ministries of Education, Universities, Teachers' Associations, etc.) (Kyle et al., 1991).

One of the steps that can be taken in any given country in order to optimise the few resources available in didactic research and innovation, is to create a community of 'team builders' including, at first, not only university lecturers in the field of science education, but also teachers who through their innovative work or research can make valuable contributions to the ongoing training of their peers, assuming the role of 'revitalisers'. This first stage would be aimed at organising seminars to train these revitalisers in which those attending would be provided with the opportunity of working together in certain depth towards renewing science teaching and particularly ongoing teacher training. These seminars must be long enough and have a clear enough thread in order to be successful in encouraging the teachers participating to:

- Delve deeper into the renovation of science teaching and collectively absorb the contributions made by innovation and research in the field of Science Education
- Exchange or share their teaching experience in order to establish and consolidate bonds among those participating and
- Form a united Group capable of effectively promoting ongoing teacher

These plans to train trainers have been put into practice in various countries and have been generally speaking highly successful, both in terms of the training received by those attending the courses and above all, of the role they have played after such permanent training programmes.

Conclusions

In summary, two changes are proposed in order to develop effective permanent teacher training programmes that allow new curricula of a constructivist nature to become more widely known and used:

- Consider ongoing training as a collective research task based on the science teaching/learning problems that arise in teachers' everyday professional life.
- Promote the creation of a community of Trainers of Trainers that can revitalise and advise the rest of teachers and foster the creation of work teams linked to the community of researchers and innovators in the field of Science Education.

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