IIEP research and studies programme

The development of human resources: the provision of science education in secondary schools

Issues in science teacher education

Beatrice Avalos

UNESCO

International Institute for Educational Planning

Issues in science teacher education

This study has been prepared under the auspices of the project on 'Planning science education provision in general secondary schools' directed by Françoise Caillods with Gabriele Göttelmann-Duret

Issues in science teacher education

Beatrice Avalos

Paris 1995
UNESCO: International Institute for Educational Planning

The views and opinions expressed in this volume are those of the author and do not necessarily represent the views of UNESCO or of the IIEP. The designations employed and the presentation of material throughout this review do not imply the expression of any opinion whatsoever on the part of UNESCO or IIEP concerning the legal status of any country, territory, city or area of its authorities, or concerning its frontiers or boundaries.

The publication costs of this study have been covered by a grant-in-aid offered by UNESCO and by voluntary contributions made by several Member States of UNESCO, the list of which will be found at the end of the volume.

This volume has been typeset using IIEP's computer facilities
and has been printed in IIEP's printshop.

International Institute for Educational Planning
7 - 9 rue Eugène-Delacroix, 75116 Paris

© UNESCO April 1995 IIEP/ph

Provision of science education in secondary schools

One of the major challenges facing human resources planning is dealing with the uneven level of technological development in different countries. The world has witnessed a huge scientific and technological explosion in recent decades; but not all societies have been equally affected by this process. Yet the ability to master and apply science and technology are indispensable to the process of modernization and development of economies.

Well aware of this fact as early as the 1960s, developing countries embarked on programmes to support the development of science education at secondary and higher education levels. Much has been achieved and the number of pupils and students enrolled in science courses has increased almost everywhere. However, expectations have rarely been met and lack of science trained personnel at higher and middle levels continues to hamper the socio-economic development of many countries. The reasons for this state of affairs are many: well trained and motivated science teachers have remained in short supply in most countries; curriculum reforms have not been implemented as planned either because the necessary resources have not been available or because it takes time in any case for schools and teachers to change their habits and teaching methods. More recently, science education seems to have particularly suffered from the economic austerity which has led to a decrease in real terms of the resources allocated to education in a number of countries. All these problems have been aggravated by lack of co-ordination between the numerous administrations and institutions concerned with secondary education and by insufficient planning. As a result, science education in a large number of countries is still in a critical state.

The overall objective of the IIEP research project on planning the provision of science education is to appraise the state of secondary school science in a range of developing countries and to reinforce national capacities to plan and manage this education in ways which will contribute to human resource development.

Studies and monographs undertaken under this project specifically aim at:

(i) establishing the condition of science education at the secondary level in countries at different levels of economic development;

(ii) developing techniques and indicators of use to the planner in assessing science education provision;

(iii) identifying strategies for providing science education in a more effective way; and

(iv) measuring the impact of science education on human resource development.

The project focuses on general secondary education. There is little point in trying to implement policies aimed at strengthening scientific training in higher education if students at the lower levels are ill-prepared. Another reason for this choice is that development depends not only on a few highly trained science specialists but also on the existence of a well trained middle level workforce and on a science-literate population. In a context of economic uncertainty and rapid technical change, it is all the more important to improve the quality and flexibility of the workforce and seek more effective methods of training. The better the initial education provision, especially in science, the easier it will be to provide specific training later and to organize re-training.

The implementation of an education designed to form inquisitive attitudes in students, encourage understanding and problem solving rather than rote learning – an education aimed at creating a scientific spirit – however, raises a series of problems. Many pupils are not interested or quickly loose their interest in science because, as from the way they are taught, these subjects seem too difficult and abstract, and not related enough to their environment and life. The fact that science education in secondary schools is often far from attaining the fixed goals seems, to a large extent, related to, or at least reinforced by, an inadequate preparation of science teachers for their actual tasks.

Beatrice Avalos who has had a great deal of experience in the area of teacher training, particularly in Latin America and Asia, shows in the present monograph that the tackling of new challenges and directions in science education – such as 'integrated' pluridisciplinary approaches to science teaching, 'science for all' and application of science in the solving of technological and societal problems – requires new concepts and new patterns of science teacher training. She draws lessons from available research as to the main problems, achievements and limitations of most initial and in-service science teacher-training programmes as they exist today and subsequently presents a certain number of particularly promising innovatory programmes which are presently being implemented in various countries of the world.

Contents

Chapter I
Challenges and directions in science education

Despite three decades of curriculum and methodology renewal in science education, there is still general concern about the quality of school science teaching. Sources of this concern are various and refer, among other things, to student achievement, to the relationship between curriculum implementation (what really takes place in the classroom and laboratory) and the intention of its producers, and to the alienation of science teaching from issues of cultural, social and technological concern. Science curriculum in less developed countries although expected to provide information and skills for development (its goals often being linked to agriculture and the rural economy) in practice is taught mechanically by teachers who feel uncomfortable in their role of applying science in such ways. And in countries aiming at growth in industrial output, although science education is considered an important factor, its quality is often viewed as far from satisfactory.

However, there have been dramatic changes in the concepts of science education. In one sense, the positivist view that science education is teaching about an objective universe 'out there' no longer represents the only assumption governing such education, though other and newer perspectives are not yet widely accepted by science educators (Summers, 1982; Burbules et Linn, 1991). In another sense, the widespread assumption that science is the work of specialists and therefore confined to those with special abilities for undertaking hard, experimental work, is challenged today by the view that scientific knowledge for the understanding of everyday problems can be part of the equipment of every person ('science for all') and should be taught in schools from that perspective. The social responsibility of scientists, highlighted in the dilemmas of post-war nuclear armament build-up, is examined today in relation to issues of environmental damage. Today we consider science education not just as an aggregate of science subjects but as preparing young people, through an integrated understanding of nature, to be part of a world that requires their participation if it is to remain habitable.

1. Towards new principles of science education

More specifically, changes in the outlook of science education have meant an emphasis on certain principles, the implementation of which poses new challenges in the training of science teachers: integration, balance between content and process in learning, openness in content and teaching/learning perspectives, social relevance, and the learner as the starting-point of science education. These principles are outlined below.

1.1 Integration

This principle is applied in several forms. Layton (1988) uses the word 'integrality' to indicate a trend towards organizing information from the sciences around unifying themes which, in practice, has meant that in many school systems, at the primary and early secondary level, young people learn about science or 'natural science' rather than about botany, hygiene, physics, chemistry or biology[1]. Integration has also meant providing educational stimulus for students to use in a meaningful way multiple sources of information relating science to the real world (Burbules; Linn, 1991). The more current sense of integration is explored through a number of special programmes for science and technology (Layton, 1988; Sabrovsky, 1992). Another form of integration or integrality, as defined by Layton, refers to the continuity of science and technology education from early on through to adult life.

1. For example, the lower secondary science curriculum in Papua New Guinea has the following unit theme distribution: introduction to science, the sun and the earth, matter, living things, heat energy, electricity, changes, how plants feed, how animals feed, invisible fields (magnetism and gravity), growth and reproduction, forces, work and energy, the air around us, communication (sound), ecology, our body, chemistry, light, microbiology, geology, traditional technology (biological and physical science themes from agriculture).

1.2 Content and process

One of the most fundamental changes occurring from the seventies onwards in science education was a shift of emphasis from learning the contents of science (according to the inner structure of each science discipline) to becoming involved in the science processes by which scientists develop their knowledge base. Essentially, this meant science learning as heuristics ('discovery learning'), not a new approach in pedagogy, as its links to John Dewey's experimental or project learning proposals at the beginning of the century could be easily identified. Fensham (1992) notes the crucial role of Schwabb (1962) in the early sixties in promoting a move from classroom teaching to laboratory discovery in schools:

> *"To teach science as inquiry, he suggested that two changes were needed in the role of the laboratory. Firstly, a substantial part of the laboratory work should be made to lead rather than lag the classroom phase of science teaching. Secondly, the demonstration function of the laboratory should be subordinate to two other functions, namely, to provide a tangible experience of some of the problems of acquiring data dealt with in science, and to provide occasions for an invitation to conduct miniature but exemplary programs of enquiry".* *Schwabb, 1962.*

While public acknowledgment of the importance of process in the teaching and learning of science is now widespread, there is growing concern that the balance may have been tipped too much and that science learning as such may be suffering as a consequence. One of the criticisms is that the strong emphasis on laboratory-based science may have lead to misrepresent science as an ability in the exclusive domain of experimental scientists, by placing more emphasis on the discovery aspects of the experiment rather than on the thinking, analytical processes students should experience and engage in. Also, an emphasis in the process skills which are involved in laboratory work without proper understanding of the concepts and theories behind its activities truncates science learning Tamir (1989). Current research results (Osborne; Freyberg, 1985; Driver, 1988) indicate that science learning occurs within 'specific content domains', and that therefore all process-centred work needs to take place within the context of specific conceptual understanding.

Millar; Driver (1987) have indicated that the 'process' emphasis in science teaching contradicts the nature of science, what is known about how learning occurs and how science can be taught. They do not deny that there is room for the learning of processes, but disagree with according to these processes a role of ends when they really are no more than means. Fensham (1992) in turn notes, with some irony, that the atomized version of process teaching which converts science processes into objectives to be learned has become part and parcel of the primary school curriculum while content-centred learning has been restricted to upper secondary education. Nur (1993), referring to the example of new science curricula in Indonesia, indicates that it is precisely not meant to lead pupils to become 'little scientists'. The Indonesian curriculum is based on the assumption that mastery of the scientific method is a secondary objective to the main one of having students develop "a critical and orderly way of thinking" and to become "creative, innovative, tolerant, independent, competent in communicating, environmentally conscious and technologically knowledgeable".

The above viewpoints represent therefore a call for caution in relation to process-centred science learning and a reminder that there is an integral connection between learning science through its inquiry processes and the specific content context in which this investigation and learning occur.

1.3 Science for all

Another, of what one might term revolutionary changes in science education, has been the view, and its implementation in curriculum renewal, that there is a solid scientific base that everybody may reach which is equivalent to understanding the uses of science in everyday life, a science content that is teachable to all pupils and for which means exist and costs can be met (Gilbert, 1989). The rationale behind this view of science as well as an obvious concern to demystify it, has been a view of science as more broadly related to people and their well-being, that is, science with a social dimension. Science, according to Layton (1988) is no longer a purely "scientific or technical problem for individuals, but ... a 'people problem' with a strong social dimension to it". In the perspective of 'science for all' science education can provide "positive experiences that would promote a climate and temper for the acceptance that science and technology can improve the quality of life and can contribute to national development and modernization" (APEID/UNESCO, 1989, p. 13). Many of the developing countries, with this orientation, have worked on new curricula with a broader, more integrated and flexible base relevant to the lifestyles of different population groups. Such for example is the case of the science curriculum for primary and lower secondary schools in Papua New Guinea (Ross, 1993) and, as Swartland (1988) documents, in a number of southern African countries including Botswana, Lesotho and Swaziland. Strong support for the 'science for all' approach has come also from scientists, as Fensham (1992) indicates with the 1985 manifesto "Science is for everybody" of the Royal Society in Britain:

> *"A proper science education at school it states, must provide the basis for an adequate understanding of science which is then to be added to throughout life. This understanding includes not just facts but the methods of science and its limitations as well as an appreciation of the practical and social implications. The manifesto claims that some understanding of statistics including ideas of risk, uncertainty, ratios and variability are so intrinsic to the method of science and to understanding many personal and public issues, that they should be goals of all science curricula. This manifesto calls for a very different sort of curriculum for the whole of the school population. It thus gives strong support for Science for All".*

1.4 Science, technology and society

Very much linked to the 'science for all' perspective is an emphasis on the links in the school curriculum of science, technology and social issues. It is considered that appropriate science education programmes should "provide all segments of society with... an appreciation of the role of science and technology in meeting the material needs of people" (APEID/UNESCO, 1989, p.7). There has been in recent years a conscious effort to develop curriculum programmes that provide school students with information and experiences relating science, technology and society. These programmes are interdisciplinary in nature, integrating elements of history, philosophy and sociology with the hard core of the sciences and technology information (Sabrovsky, 1992). Their main objectives are to broaden the scope of integrated science and science for all, and to orient them towards the development in students of a capacity to judge scientific and technological proposals with social implications. Concretely, the content of these programmes (developed in Europe and North America)[2] include knowledge about specific technological artifacts and processes, social issues derived from science and technology and exploration of the historical and epistemological foundations of the sciences. They constitute either separate curricula on science, technology and society (STS) or science teaching which includes elements of STS with greater or lesser infusion of science contents. The discussion of social issues arising from the application of science to technology is recommended as part of the activities conducted during science lessons and is seen as a powerful means of stimulating interest in the study of science (Ferreyra, 1992). Moreover, there is scope for school research projects which clearly link science, technology and everyday problems requiring the application of science to their solution.

1.5 Learner perspectives: constructivism and ethnoscience

By shifting emphases in science education from the conceptual framework of the sciences and the processes by which science discovery is achieved, constructivism has focused attention on science learning as a personal construction of meaning on the part of the learner. Its epistemological basis is traced to phenomenological theories which lay emphasis on knowledge as construction and to Piaget's cognitive developmental psychology. To integrate and become knowledgeable about something is not to have absorbed and been able to reproduce existing conceptualizations of an objective, outside reality, but to have been able to build a personal interpretative framework for the understanding of such reality. Such a process, though essentially personal, is furthered by interaction and social exchange of meanings, making knowledge in the end a social process leading to understanding that is and can be further shared with others.

2. Among these science, technology and society programmes, those which represent different types of combination with science are the *Science and technology in society* and the *Science and society* programmes in the United Kingdom, the *Chemistry in the community* programme in the USA and the *Physics curriculum development project* in Holland.

Although constructivism seen as a philosophy of knowledge acquisition and construction of meaning ('meaning-making') should find application in all forms of education[3], as an approach it has been particularly successful in influencing the field of science education. Its most important proponents are in the United Kingdom, New Zealand, Australia, and the USA and there is a growing body of research in science education that builds on this approach.

As an educational theory, those who work within a constructivist approach examine both the teaching-learning process and the learning environment (including the curricular activities) in which this process occurs. Their central concern is the learner and how she or he approaches the goal of 'meaning-making' when faced with curricular experiences in a teaching situation. Attention is placed on the prior knowledge, conceptions and beliefs that the learner holds, for example, about the natural world long before being confronted with 'official' explanations about this world. Consideration is given also to non-cognitive factors such as openness and willingness to learn and the possession of a sense of purpose affecting the learner's readiness to examine the learning stimuli presented. In other words a key factor in learning is not so much the teacher or teaching materials *per se* but the learner's acceptance of responsibility for learning, or more specifically, learner motivation (Osborne; Wittrock, 1983). Given this standpoint, to learn science is a process by which teacher and materials, as facilitators, help learners to use their prior conceptual frameworks in the interpretation and construction of new or revised meanings. For this learning to occur most authors (Osborne; Wittrock, 1983; Gunstone, 1988; Driver, 1988) who describe the theory behind constructivism coincide in a number of conditions that need to be supported:

- learner attention and motivation towards the learning processes involved;

3. Carvalho, Pessoa de (1992) refers to studies in Brazil which are beginning to be conducted in the field of geography on how children read maps, and how they build their concepts of longitude and latitude.

- learner active involvement in the bringing out of knowledge reserves (concepts and meaning structures) to help in making sense of new knowledge;
- learner restructuring and fine-tuning of prior understandings in order to facilitate the generation of sensible explanations;
- relating of these explanations back to other knowledge-structures which are contained in 'long-term memory'.

A variation of the constructivist approach, considered for contexts with great linguistic and cultural diversity such as Papua New Guinea, is the application of the principles of ethnoscience to science education. Ethnoscience is defined as the study of knowledge in its cultural context and of its use as a form of adaptation to the world (Vlaardingerbroek, 1990). According to Erickson (1986) there are three areas of cultural differences that may influence the teaching and learning of science: differences in cognition, differences in speaking and listening, and conflicts present at intercultural borders. In relation to cognition, there is reference to the link between science education and the explanatory concepts of different cultural groups in the work of Bulmer in Papua New Guinea (1971); and, in the work of Gardner in Papua New Guinea, Australia, Philippines, Israel and Britain on the effect on learning of linguistic variations and interpretations of science concepts (as reported by Fensham, 1988; George, 1991). As Vlaardingerbroek (1990) indicates, aspects of ethnoscience have been included in the primary and lower secondary science curriculum in Papua New Guinea, and teachers and students are encouraged to discuss "traditional views on such matters as the formation of the earth, and seasonal/human behaviour interactions" although these concepts contradict Western perspectives. He notes that the "most striking inclusion of ethnoscience in the syllabus from the Western scientific philosophical perspective would be that of *sanguma* (malevolent spirit beings) and *puripuri* (magic) in a Grade 8 unit dealing with force fields, the writers going so far as to inform teachers that these phenomena exhibit many characteristics of a 'zone of influence' the term also used for physical force fields as recognised by Western science".

A certain number of studies are being conducted in other contexts to examine the presence of socio/cultural factors in conceptualizations of students which are present at the time they learn Western science.

George (1989) reviewed some of these and presented her own investigation of what she calls 'street science' found among children in Trinidad and Tobago; a similar study was conducted by Mohapatra (1991) in India.

2. Consequences for science teaching and teacher education

The appropriate setting of a learning environment and teaching strategies follow from the above conditions, and a variety of suggestions in this respect are offered by those who advocate the constructivist approach. In relation to the teaching and learning of physics McDermott (1993) outlines, for example, a series of principles resulting from research based on the constructivist tenets which is contrasted with the largely teacher-centred and top-down general to the particular approach, that she terms 'traditional' to:

- achieve functional understanding of physics concepts, questions that require qualitative reasoning and verbal explanation are essential;
- develop a coherent conceptual framework, students need to participate in the process of constructing qualitative models that help them understand relationships and differences among concepts;
- overcome conceptual difficulties, these need to be explicitly addressed by repeated challenges in more than one context;
- achieve growth in reasoning ability, scientific reasoning skills must be expressly cultivated;
- achieve connections among concepts, formal representations, and the real world, students need explicit practice in interpreting physics formalism and relating it to the real world;
- develop functional understanding, students must be intellectually active; teaching by telling is therefore an ineffective mode of instruction for most students.

Gunstone (1988), in particular, emphasizes among other strategies the use of probes in the teaching of science:

> *"The methods used to probe students' ideas/beliefs are also, almost by definition, excellent teaching/learning strategies. In part, these probes of understanding have been used by researchers because of the ways they promote student introspection and hypothesizing about phenomena. These qualities make them excellent teaching approaches, although their use inevitably requires a classroom where genuine discussion and debate are accepted as appropriate learning behaviours by both teacher and students".*
> *Gunstone, 1988.*

The above-mentioned new or changed approaches to science education pose a series of questions relating to teacher education. To what extent are prospective teachers being made aware of how these approaches could modify the practices that they might have experienced during their own schooling? In what ways are those responsible for the training of science teachers keeping abreast of these orientations, examining them and considering their feasibility within the context of teacher education? How are concrete requirements being met, through teacher training, to stimulate more young people to interest themselves in science and the uses of science as well as technology? What examples exist of alternative teacher-training structures that could assist the development of a better content foundation on the part of science teachers and an improved capacity to teach these subjects. Is it the same to train a teacher for 'integrated science' teaching or for subject specialization in, for example, an upper secondary science stream?

It is the purpose of this monograph to provide information and discussion about some of the above issues with a *particular emphasis* on the *current situation* and *changes* that are needed to improve the quality of secondary science teacher training in the light of the *newer orientations* of science education. While the material conditions within which science teacher training takes place condition the quality of many of the processes that are used (particularly, resources for laboratory equipment and renewable materials, texts, guides, etc.), this monograph does not directly address these requirements. As indicated its focus is mostly on providing material for an informed examination of the patterns, content and process of training secondary science teachers within perspectives that see 'science literacy for all' as a goal and see also the need for a science/technology emphasis not only oriented to industrialized societies but to societies where simpler technologies can affect the quality of everyday life to an important extent. With the exception of a chapter on research results, *Chapter III*, where most of the work reviewed is from developed countries, special attention is given to some developing country contexts in Asia/Pacific and Latin America. Many of the countries in these regions are strongly committed to modernization strategies and to bringing about economic development parallel to and as a condition of a better quality of life for their people. They view the development of science and technology as an important factor, and understand that in this development, *teachers* and *teacher training* have an important role to play.

Chapter II

Science teaching and teacher training: recent concepts, objectives and options

1. Concepts and objectives

The history of curriculum waves and emphases in the last 40 years is also the history of views about the kind of science teacher that is needed. This may be true simply because there is no real alternative to the fact that teaching and learning, mediated by materials, packages, media, strategies, skills and other means of human communication, functions mainly as a process of interaction among persons. Unfortunately, more often than not, the human actors (teachers and learners) are neglected not in the discourse, but in the design and implementation of curriculum reform.

The approaches and format used in teacher training should be closely related to the kind of teacher needed for the education system in a particular country context, to the particular knowledge area in its current state of development, and to what research and experience indicate as sound teaching practices for the purposes sought. Yet, this is often not the case for a number of reasons mostly related to the weight of traditions and institutions, availability of resources and, more often than one would wish, the people who remain within the educational sector for too long while lacking opportunities or desire to renew themselves. As a result, the newly arrived classroom teacher may have criticisms of classroom teaching thrust upon him or her by inspectors who function within older schemes of teaching, and experienced teachers may be forced to accept instructions on curriculum renewal without the opportunity or competence for knowledgeable and critical participation.

Fortunately, both the research literature and international development institutions are giving increased attention to the improvement of teacher-training processes, both at pre-service and in-service levels, recognizing, probably, that these may constitute a significant way of influencing the quality of teaching and learning within a country context.

1.1 A conceptual framework

To facilitate the discussion of how science teachers are or could be trained, there is some value in using a conceptual framework that depicts factors related to teacher training and allows room for the incorporation of current theoretical approaches to science teaching and the role of teachers. Such is the model depicted in *Figure 1.*

1.2 The model

In *Figure 1* the process of teacher training appears affected by two sets of external factors. At one end of the process are contextual conditions in a concrete setting, such as the educational structure, characteristics of the science curriculum and resources, and roles assigned to the teacher. Context also encompasses theoretical views about the nature of science, its role in society and how best it should be taught for learning to occur. Despite common trends, these views are variable among educators and within institutions. At the other end is the teacher trainee and what he or she brings to the process in terms of specific science knowledge and understanding, and general attitudes and beliefs about science, teaching and learning.

The training process of a science teacher, as represented in the ellipse (*Figure 1*) and in relation to its curriculum orientation and training approach, can be viewed through positions along a continuum. Its curriculum orientation expressed in the structuring of subject content, pedagogy and teaching practice, can be materialized in patterns using strictly sequential to concurrent formats.

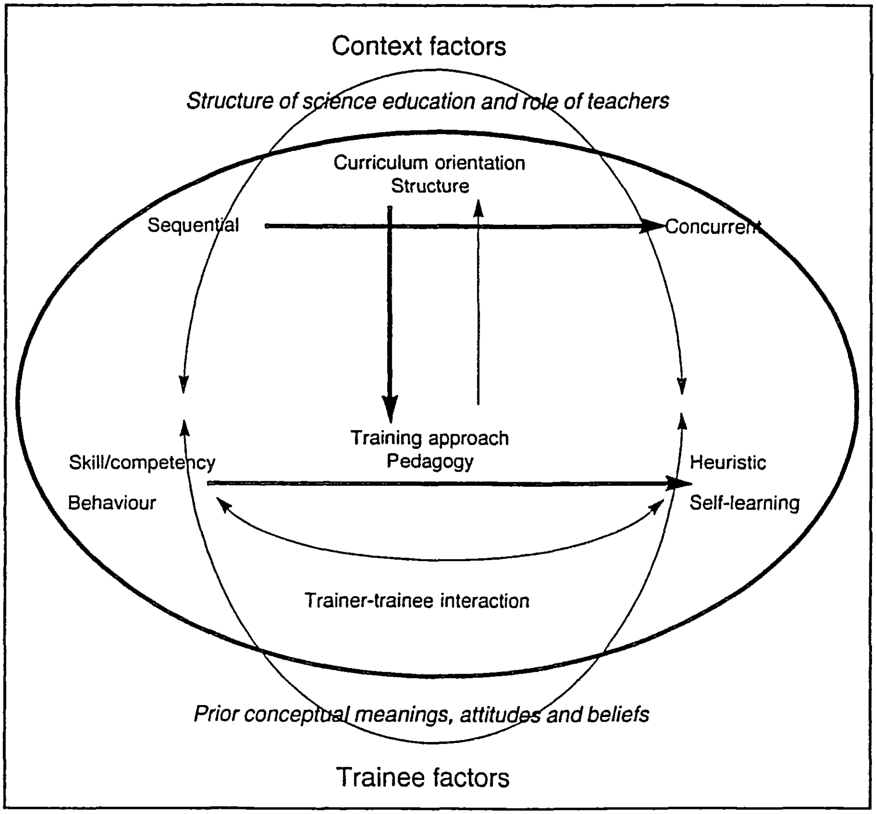


Figure 1. Teacher training: conditioning factors, structure and process orientations

A sequential programme offers content followed by pedagogy and this in turn followed by some form of extended practice. A model may be concurrent in relation to content and pedagogy or it may include from its beginning forms of teaching experience. From the perspective of its training approach, patterns may vary from the use of highly structured teaching/learning procedures to strong emphasis on self-learning, with symmetry in the interactive trainee/trainer relationships being more or less accentuated along the continuum[4]. While the structure of training strongly determines what is possible in terms of training approaches and procedures, the reverse may also be true, though in a weaker form, as indicated in *Figure 1* by the lighter line directed from training approaches to curriculum orientation.

2. Pedagogy

'Pedagogy', almost a forgotten word in the English language and only recently resuscitated in its meaning as 'the science of teaching' (Oxford Dictionary), brings us to consideration of those experiences that affect the quality of the teaching process. It is at least an accepted fact that teachers do not emerge from their initial teacher training as fully fledged 'good' teachers. Novice teachers, as Gilbert (1989) indicates, move at different rates from the 'survival' to 'identification' phases in which they are able "to meet fundamental professional matters". Novice teachers have just become 'initiated' and need time and further training experiences (in-service opportunities) to conduct their teaching in ways that will be most meaningful for the learning and overall education of their students. However, 'initiation processes' are important and by implication so also is the form in which initial training is conducted. Here, in relation to the 'pedagogy' component of teacher training, we will consider discussions centred around the teacher's profile, procedures, student teacher entry characteristics, and content.

4. The distinction between a behaviourist, skill-centred approach to teacher-training procedures and those which, while emphasizing a learner-centred approach, give a greater or lesser role to teacher/student interactions is explained in more detail in a study on the training of primary teachers (Avalos, 1992).

2.1 *The teacher's profile*

There is a growing and rich literature which looks at more descriptive formulations of the role of science teachers in the light of constructivist learning theories and of the principles of making the role of science understandable to as many as possible. A greater emphasis is being placed on teachers who have conceptual understanding of what they have to teach and who are able to reflect on the nature of their knowledge (metacognition) in order to understand also the processes by which their students learn (Baird; Mitchell, 1991; McDermott, 1993). This of necessity requires adequate content knowledge of "the phenomena, the methods, and the concepts, principles, theories which constitute the science they are teaching" (Hewson; Hewson, 1988). Teachers also have to be able to reach students at the place where they are, using instructional strategies that will enable them to build on students' existing conceptual frameworks; this often requires a greater understanding of the historical processes which have led to scientific discoveries as well as of the cultural beliefs of the particular contexts in which teaching is taking place (George, 1989). Finally, teachers need the strategy alternatives that will enable to work out with students the means of seeing the relevance of science and of engaging in projects which have social utility (Muhlebach, 1992).

2.2 *Procedural principles*

As we move from statements about the type of teacher that it is desirable to educate to procedural principles to be applied in teacher training, we need to refer back to *Figure 1* of this monograph. There we find illustrated a procedural continuum from what could be a heavily prescriptive type of training approach to an 'open', learner-centred one, that places more emphasis on the creative resourcefulness of teachers than on the provision of structured teaching formats. Linking one extreme with the other is the 'interactive' character of the training programme, that is, the degree to which the teacher educators are dominant figures at one extreme or the degree to which the trainee is the centre of attention at the other, with points along the continuum indicating more or less symmetrical types of training relationships. The more the interactive processes are symmetrical, the clearer are the contributing roles of trainer and trainee but also the closer are they to the common aim of a self-sufficient, knowledgeable and competent teacher as an outcome. This means that the strong emphasis on skills and competencies is dimmed (not done away with) to give way to less structured forms of 'initiating' teachers into the profession; and that more emphasis is placed on a reflective analysis of the teaching experience (Schön, 1987, 1991)[5]. The closer the training procedures move to the open/end of the continuum and the more its interaction forms are symmetrical, the further away will the training approach be from a 'technical rationality' model with its strong reliance on prescriptions for teaching (still strongly advocated in some developing country contexts). If we take notice of the 'science for all' and the 'constructivist' perspectives in science education, it is fair to say that a science teacher education that is closer to the 'open' end of the continuum would also be closer to those perspectives. ***Figure 2***, reproduced from Novak; Gowin (1984), illustrates well the relationships between such extreme approaches as noted from the perspective of the science learner.

In considering the teaching procedures future teachers should be aware of, other related aspects should be noted. One, for example, is that whatever procedures are deemed appropriate these should be foreshadowed in the training procedures used by teacher educators (Gilbert, 1989); this then requires a 'reflective turn' on the part of staff in training institutions.

5. Adler (1991) notes three different meanings given to the concept of 'reflective practitioner' by those who advocate it. Donald Cruikshank at Ohio State University links 'reflective practice' to a labortory situation where trainee teachers analyse a peer or teacher training's lesson in terms of teaching skills which have research support for their effectiveness. Donald Schön at the Massachusetts *Institute of Technology* sees the "reflective practitioner as a teacher who reflects at the time of his or her actions". Thus teacher training must emphasize 'learning by doing' and coaching as guidance towards the recognition of good practice, the building of images of competences and of thinking while acting. Kenneth Zeichner from the *University of Wisconsin* speaks of "reflection as *critical inquiry*" He considers that reflection is aimed at three targets and levels: (a) the technical level concerned with the "efficient application of professional knowledge to given ends", (b) reflection on the situational and institutional contexts where teaching takes place, and (c) reflection about moral and social issues affecting education in its wider societal dimensions.

Figure 2. Types of learning

MEANINGFUL LEARNING	Clarification of relationships between concepts	Well-designed auto-tutorial instruction	Scientific research New music or Architecture
	Lecture or most textbook presentations	School laboratory work	Most routine 'research' or intellectual production
ROTE LEARNING	Multiplication tables	Applying formula to solve problems	Trial and error 'puzzle' solutions
	RECEPTION LEARNING	GUIDED DISCOVERY LEARNING	AUTONOMOUS DISCOVERY LEARNING

Another, as indicated by Gunstone; Slattery; Baird; Northfield (1993), is that it is more important for student teachers to model the manner in which teaching will be done in the future and to enact it in real teaching situations, rather than learn to teach by mimicking pupil roles.

2.3 *Knowledge and attitudes in student teachers*

Returning to our conceptual framework in *Figure 1*, there is an indication that entry characteristics of student teachers (including their meanings, attitudes and beliefs) are an important factor that affects the process of training. This means that in order to make better sense of new knowledge structures and the specifics of science teaching, student teachers need assistance in bringing their meaning structures and attitudes to consciousness and in making these accessible to trainers. For the purpose of examining student teachers' views about teaching and learning, their understanding of the contents they will teach and their own ideas of self, Gunstone; Slattery; Bird; Northfield (1993) indicate the need "to seek out feedback and provide experiences and follow-up activities to allow student teachers to discuss, evaluate, rethink, and (perhaps) restructure their ideas". Examples of some of these procedures and of their effects in different training programmes are presented in *Chapter III* of this monograph.

2.4 *Pedagogical content knowledge*

While the particular type of courses that may be offered at the time of teacher training can vary from institution to institution there are two types of activities which, seen in the context of science teacher training, are generally important. These activities more specifically constitute the bridge between science content and pedagogy. The first activity are courses or seminar/workshop situations organized to examine the particular structure of the sciences and the history of its development. In an article arguing for the inclusion of a philosophy of science course in the teacher-training curriculum, Summers (1982) notes that "it should be central to the practice of any profession that its members are able to justify what they do and how they do it"; and that such justification requires knowledge of the epistemological basis of the subject about which one claims expertise. In this respect, there is a growing body of literature on the relationship between the epistemology of science and school science education that should not be ignored by future science teachers; particularly also because judgment is required in view of the number of curriculum projects over the last thirty years that represent different views about science. Awareness of the epistemological foundations of science as discussed today is also relevant to the way in which teachers will come to understand and practice their teaching, although this is not necessarily so (Lederman; Zeidler, 1987). Styles cannot be changed simply by exhortation or mechanical training. There is a better chance that teachers will adopt or change a style if they are able to understand why one strategy is better than another; both in terms of presenting a fair view of the subject and of furthering pupil learning.

That there is need for knowledge about philosophy of science on the part of intending teachers has been recognized by Asian educators (APEID meeting on the *Training of science teachers and teacher educators* in Quezon, Philippines, 1984). However, the establishment of such a course, especially if it is of a lecture type, requires that it be taught by persons who are at home in the field; seminar activities which stimulate reflective reading on topics related to the history of science and to its epistemological foundations may be a better way of introducing students to the issues at stake.

The second set of activities that bridge the gap between science and teaching are those that involve the transformation of substantive knowledge (acquired through science learning) into 'knowledge for teaching' (Grossman; Wilson; Shulman, 1989). In enumerating the knowledge areas that all student teachers need to encounter, Shulman (1987) makes a distinction between 'curriculum knowledge' related to the materials and programmes that 'serve as tools of the trade' for teachers, and 'pedagogical content knowledge' Although both are important, Shulman considers 'pedagogical content knowledge' a special area of interest because:

> *". . . it identifies the distinctive bodies of knowledge for teaching. It represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction".*
> *Shulman, 1987.*

Training activities geared specifically to preparing a science graduate to teach need to contemplate not only instruction on the curriculum and specific teaching procedures, but more importantly the development of the ability to reason 'pedagogically' on the part of student teachers in order to convert substantive knowledge into teachable knowledge and experiment with how this can be done. This requires more than that achieved in the well-known special methods courses. Examples of training programmes attempting to develop this 'pedagogic content knowledge' and the tools for teaching towards achieving learning objectives, are presented in *Chapter III* of the monograph. Suffice it to say here that the specific science training course is central to the preparation of teachers because it is here that the student teacher meets the science subjects with their logic, their problems, their concepts and applications and examines these from the perspective of bringing them to the learner in a classroom situation. While it rests on the solidity of the school curriculum and whatever available teaching strategies can be used (including laboratory work) special methods' courses need to be more than this; they must further student teachers' understanding of science as a field of knowledge to be made part of school pupils' knowledge repertoire.

3. Policy options and patterns of science teacher training

3.1 Curriculum orientation in science programmes

Current views about science education and science teaching are influenced by the various perspectives which will be discussed in the subsequent sections of this paper. A brief perusal of documentation relating to the Asian and Latin American regions indicates that in the school curricula of these regions there is a mixture of four perspectives which are not necessarily mutually exclusive: the 'academic' perspective of providing enough science knowledge to ensure adequate preparation for science higher education, 'process-oriented' science embedded in integrated-science courses as well as in the academic stream, the 'science for all' perspective contained in curricula with contents of social relevance, and the 'science and technology' approach which, while including contents of social relevance, is valued also in its utility for economic development.[6]

At least three of the four perspectives noted above are reflected in the differing emphases of the secondary school curriculum as present in its general education component (not technical-vocational streams). As seen from the countries listed in the table below, almost all include some form of integrated science course in the lower secondary cycle, referred to as 'general science', with physics, biology, some chemistry and, less frequently, environmental and technological contents. The upper secondary cycle, on the other hand, with its academic purpose of preparing for university studies, retains the teaching of physics, chemistry and biology in the form of discrete subjects.

Less clear from *Table 1*, however, is the place that the 'science for all' perspective has within the integrated science courses in lower secondary. For example, in Latin America, a number of countries have not had a major curriculum change since the early seventies, when process-oriented science was introduced as a way of knowledge and of accumulating knowledge about the world (Ware, 1992); this being more a teaching/learning approach following the steps of the scientific method, than a set of contents that could be related to concrete issues such as health, environment, and 'everyday coping' (Roberts, 1988).

6. This view is advocated with particular strength in the recently published report by ECLA/UNESCO on *Education and knowledge*, 1992. The report highlights as a key issue that a deliberate effort to incorporate and disseminate systematically the elements of technical progress is a crucial element for changes in production in Latin America which will be compatible with its current process of democratization and its need for greater social equity. Education or human resource development is dicussed as one of the main factors in making possible the needed scientific and technological revolution, increased competitive productivity and a better way of life for the population.

Table 1. Secondary science curriculum in Latin America and Asia/ Pacific

Country	Grade	Curriculum emphasis – date
Latin America		
Argentina	7 - 9	Integrated science; scientific process and skills; some technology concepts (1989)
	11 - 12	Single sciences – academic (science concepts)
Bolivia	9	Integrated science
	10	Integrated biology; scientific attitudes (1975)
	11 - 12	Single sciences – academic
Chile	9 - 12	Single sciences – conceptual, academic (1989)
Mexico	7 - 9	Integrated science – sciences processes – concepts and applications (1975)
	10 - 12	Single science – academic – pre university courses
Venezuela	10 - 12	Single science – academic (1972)
Asia/Pacific		
Bangladesh	6 - 8	General science
	9 - 10	General science for science stream
	11 - 12	Single sciences – for science stream
India	9 - 10	Physics, chemistry and biology; thematic with concepts, work relevance (1988)
	11 - 12	Single sciences as electives
Malaysia	7 - 9	Integrated science – 'science for all'
	10 - 11	Single sciences or general science 'for all'
	12 - 13	Single sciences – academic (1989)
Nepal	6 - 10	Science combination
Pakistan	9 - 10	Single sciences or general science
	11 - 12	Single sciences – academic
Papua New Guinea	7 - 10	Integrated science – science for all
	11 - 12	Single sciences – academic
Philippines	7	Integrated science
	8 - 10	Single sciences – academic
Korea	7 - 9	General science in three levels
	10 - 12	Single sciences – academic

* Date of issue os syllabi indicated as in place circa 1990.
Sources: Modified version of Holbrook in Ware (1992); UNESCO, 1985; UNESCO, 1989.

Thus, while there are numerous declarations about 'science for all' as a programme for science education in at least the primary and lower secondary levels, neither curriculum nor teacher-training procedures may have been altered accordingly. Equally the discipline-centred orientation of science teaching in upper-secondary, even in the non-science stream of a diversified curriculum, indicates its strong orientation towards being a first step to higher education studies (Caillods; Göttelmann-Duret, 1991).

This 'academic' orientation of science teaching results in curricula and teaching efforts being adapted to respond to university science faculty demands for science concepts' learning[7] and makes any attempt to introduce an integrated, 'science for all' approach in upper secondary, very difficult; and doubly so because teachers feel the task is too much for them (see *Box 1*).

The most recent popular and forceful orientation of policy statements on science teaching, however, stresses its role in furthering national and economic development and a technological society, as well as of influencing the population to understand and value the uses of science (see *Boxes 2 and 3*). As indicated elsewhere, countries in South-East Asia and Latin America have as a major concern the need to become competitive in worldwide markets and believe that education is a powerful contributor to this goal.

7. In the respect, it is interesting that the curricular changes made to the Chilean secondary education in 1989 reintroduce in the natural sciences course of the lower secondary cycle a distinct-subject perspective (chemistry, physics and biology) which was not in the earlier programme. It also reinserts the subjects of physics and chemistry in the context of a science stream, which had been left entirely as electives in an earlier change (1985). In the revision of the syllabae there was strong participation of university academics from science faculties.

Box 1. Why integrated science in upper secondary is difficult (a teacher's view)

At a private school, in the city of Santiago, integrated science is being taught successfully from Grades 7 to 10. This success is mostly due to a lengthy experience in attempting to do so, frequent teacher meetings to discuss their experiences and sufficient resources and enthusiasm and dedication of teachers. However, it has been difficult to attempt integration in Grades 11 and 12 for several reasons:

- teacher resistance as they fear the implications of having to teach concepts from sciences other than their own that they do not know well;
- lack of teacher preparation to deal with new and different topics and lack of audacity and creativity among some teachers;
- teachers, mostly as a result of inexperience and resistance to move out from their own field of specialization, have difficulties in finding unifying themes across the science disciplines;
- insufficient updated laboratory materials to carry out experiments properly; and no texts for teachers or students that illustrate integrated themes;
- students in Grades 11 and 12 specializing in science are concerned about their university entrance preparation and do not think that integrated science will help them; they put pressure on teachers to stress discipline teaching rather than integrated science.

Source: Interview with Science Department Head.

Yet, as Ware suggests (1992), in her report on *Secondary school science in developing countries*, the need to produce future scientists and technologists may not be helped by the prevalence in the existing curricula of a narrow academic approach; while the advantages that the 'science for all' approach could have within STS to motivate students may be lost:

> *"The failure of the first-wave courses to engage the interests of the majority of students which resulted in early self-selections of many talented students out of the science stream, is one good reason to delay teaching these highly abstract courses as long as possible. This also permits the teacher to reach the larger group of students with useful science information. In developing countries it is particularly important to keep science knowledge as intellectually accessible to as many students as possible for as long a period as possible. This will produce not only a more scientifically literate populace, but a larger pool of students from which to select the next generation of scientists and engineers".* *Ware, 1992.*

Box 2. The role of science education in Asia and the Pacific countries

(i) Provide positive experiences that would promote a climate and temper for the acceptance that science and technology can improve the quality of life and can contribute to national development and modernization. To achieve this, science education must be presented in a way that is flexible and sensitive to different socio-political economic and cultural conditions existing in the community.

(ii) Serve as a source of expertise for the development of indigenous science and technology and the modification of existing science and technology to suit local situations.

(iii) Restore and maintain a new balance between personal and national development and harmony with nature, through proper utilization of natural resources and development of correct attitudes and value appreciation of nature.

(iv) Widen the base from which scientists and technologists of the future can choose proper science content relevant to their own fields of specialization and the needs of the community.

(v) Increase the experience, excitement and joy of students in going through scientific processes and acquiring scientific knowledge.

APEID/UNESCO, 1985. Strategies for curriculum development and teacher training.

Box 3[8]. The Ministers of Education in Latin America

The role of science and technology will greatly decide what education is to contribute to the development of the countries in the region. In the last instance, it is the greater or lesser degree of mastery and generalization of scientific knowledge and its applications that separates and makes them (the countries in the region) more or less dependent on the nations that have this powerful instrument of progress (Mexico, Regional Meeting, 1979).

Therefore, the need of education to:

Enable all people in the region to acquire the structures, ideas, facts, and the cultural, scientific and technological contents, needed to grow through activities and creations which are set to the service of all.

UNESCO/OREALC, 1989. Bogota Regional Meeting, 1988.

8. Translated by B. Avalos.

3.2 *Teachers' roles*

Just as views on science education and the forms taken by the science curriculum are influenced by the various concerns of society, technology and academia, so also do we find that definitions of the role of teachers are linked to these views.

From the perspective of the kind of science teachers needed for the schools, we notice two poles in a continuum pointing to the science disciplines, their content and structure at one end; and at the other, to science "as knowledge resulting from the sciences aimed at improving the quality of life and further learning in the evolving work place" (Ware). According to these views, teachers have either to be specialists in one of the science disciplines of physics, chemistry, biology, widened perhaps to earth sciences, or be capable of integrated science teaching with elements of technology incorporated and able to relate science to problems of every-day life. The knowledge and teaching strategy repertoire required for these two perspectives is different and not always recognized by those who appoint science teachers nor by the teacher-training structures.

From the perspective of how teachers should teach and what strategies they should adopt, again there are two poles of a continuum: at one extreme, there is a structured, teacher-centred approach that places the main thrust of science learning on the development of specific behaviours, and on the other, there is an open view of teaching and learning, with greater emphasis on the learner, his or her prior concepts, understandings and attitudes and the strategies that stimulate motivation to become self-learners. Both orientations, however, require that teachers be fully conversant with the science concepts involved, with the processes of performing science as well as with the strategies best suited to different learners in different contexts.

The tensions between these views of science and of science teachers are embedded in professional discussions of what science teachers should be like and how they should teach. Below are two sets of statements which reflect these tensions. The first one is an attempt to make sense of the long lists of teacher requirements that are usually produced by policy makers and professionals at their gatherings. Thus the regional workshop on *Teacher training for science and technology education reform* (APEID/UNESCO, 1991) centring its attention on teacher skills and competencies noted four areas (information-processing, problem-solving, creativity and decision-making) in which teachers need competency if they are to comply with what is being expected of them in view of 'science for all', 'community development' and 'science and technology' perspectives:

"The new role expectations demand new skills and competencies of science teachers as they are, in addition to their curriculum-oriented roles, supposed to be the guides of the community in terms of new developments taking place in the fields of agriculture, medicine, communication, household technological gadgets, and others. This implies that they need competencies and skills that will equip them to meet the demands of the community which is striving everywhere to improve their quality of life. While individual teachers have played such roles on their own initiative, the sheer pace of transformation makes it implicit on teacher-education programmes to equip all teachers with such skills that would enable them to meet the comprehensive demands of learning and life. Initially, when science became part of school curriculum, it was perceived as something meant only for a select few; those who would go for higher education and become scientists. This is no longer the case now. It is fully realized that science has to be 'science for all' and as such its content, methodology, and objectives need a thorough re-definition. This has been attempted or is being attempted. At present we have gone at least one step ahead and it is now not only 'science for all' but 'science and technology for all'. From universalization of elementary education, we have moved to universalization of science education".

(APEID/UNESCO, 1991).

The second statement was the result of a workshop on the teaching of basic sciences organized by UNESCO/OREALC (1989) with the participation of a group of Latin American science educators.

While furthering considerations such as those set in the above quotation, this workshop noted that there is more than specifications of role/competencies for teachers required to produce a change of emphasis in science education. There are problems associated with traditional views about science teaching held by policy-makers, administrators and teacher trainers; too little emphasis on learner needs, curricula fraught with difficult words and traditionally prescriptive programmes of teacher training that hinder teachers entrusted with 'science for all' and 'science and technology' mandates in their tasks. For example, they indicated:

> "• *Student prior experiences still are not recognized in the teaching of Natural Sciences. Yet, motivation and learning are enhanced by 'what is already known' and so is also the individual and group creativity needed to cope with problems in the surrounding environment.*
>
> • *Excess in contents and difficult words used in teaching is what contributes to students' loss of interest in science studies and inhibits learning which is culturally relevant.*
>
> • *Efforts to change or renew scientific-technical curricula are in constant battle with traditional forms of training teachers and with routine styles existing in communities. This is coupled with the lack of an attractive teaching career that supports teachers as change agents in relation both to the student's scientific education and that of the wider society" (UNESCO/OREALC, 1989, pp. 184-185).*[9]

3.3 The structure and content of initial science teacher training

In his discussion of the dilemmas facing science education at the end of the eighties, Fensham (1988) noted the historical neglect in processes of curriculum reform of teacher education; and welcomed the new turn in projects that were recognizing the centrality of teachers even though some were still decontextualizing teachers by seeing them "as either deficient in science knowledge or in certain teaching competencies", and by being set up "to remedy the deficiency" (Fensham, 1988). What we will examine first in this section are characteristics of teacher training-processes both in terms of the structure and of the component elements of the programmes. Section 3.4 will take into account the pedagogical approaches that may influence these.

9. Translated by B. Avalos.

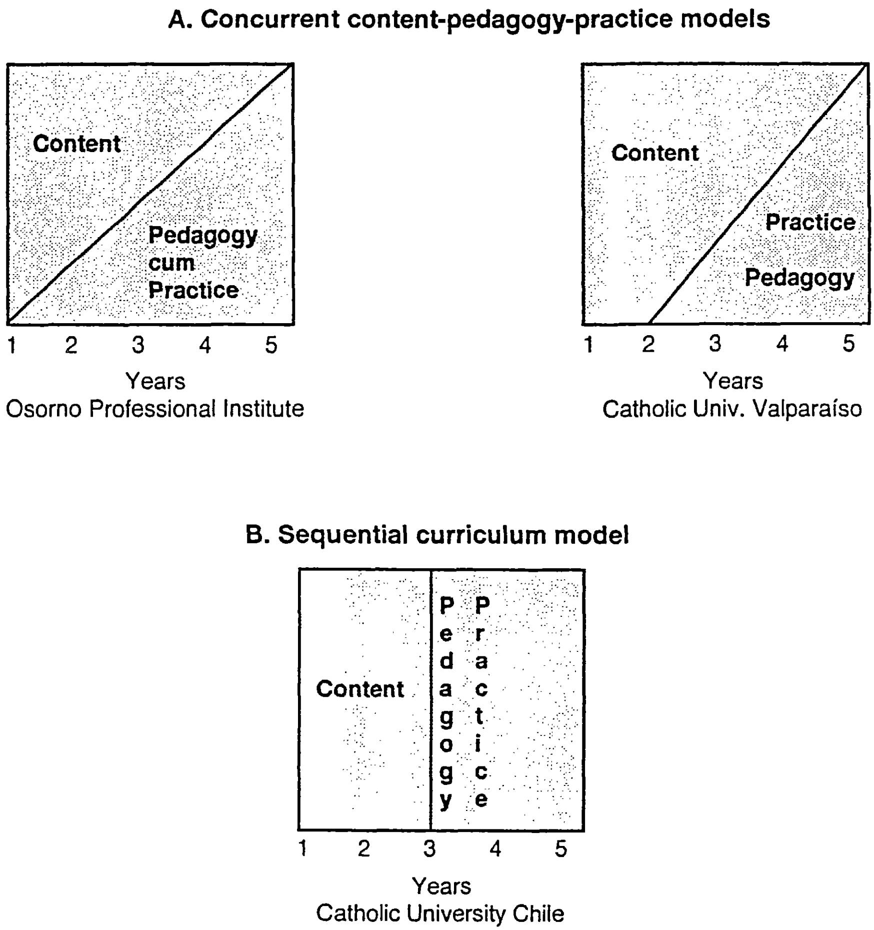


Figure 3. Secondary science teacher-training curriculum structures

Secondary teacher training in developing countries is carried out at different levels that include two or three-year certificate/diploma studies, three to four-year degree (science *cum* education) programmes and post-degree teacher-training programmes. Training is normally structured in three areas: science content (and sometimes, other general content), pedagogical training and teaching experience, including a period of teaching in schools. These studies may be offered in a sequential or concurrent manner. *Figure 3* illustrates, with the example of three programmes operating in Chile, the manner in which these contents may be organized over the total teacher-training period.

The programme offered by the Osorno Professional Institute will be examined as an example in *Chapter V*, though we note here the weaker line between content and pedagogy; it indicates a structural effort to produce integration between content and pedagogy from the start of the course of studies. In the case of the Catholic University of Chile content is clearly separate from pedagogy, while the Catholic University of Valparaíso offers a programme with gradual integration of pedagogy into content.

The scientific content of teacher training is difficult to assess given variations in the programmes involved and the requirements of the school curriculum in different countries. However, taking again the case of Chile, *Table 2* presents an example of the content in three biology teacher-training curricula (for lower and upper secondary science streams).

The training in these four universities is four and a half to five years long and is intended to prepare teachers for lower and upper secondary and for the integrated science course taught in the seventh and eighth grade curriculum of basic (primary) education. Institutions differ in the way they conceive the programme in relation to the objectives and needs of the school curriculum. The Catholic University requires all intending teacher trainees to complete an initial three-year cycle of basic science offered by the science faculties (biology, chemistry, physics and mathematics), before entering the Faculty of Education for pedagogical training.

Table 2. Science content in the curriculum of secondary school science teacher training in four Chilean universities

Courses*	Universities: Catholic University Chile	Catholic University Valparaíso	Metropolitan University	Playa Ancha University
Mathematics				
• General			2	2
• Algebra/Calculus	3			
• Algebra/Trig Analytic Geom.		2		
Chemistry				
• General/Organic/Lab. Techniques	5	2	2	3
Physics				
• General	2	2	2	2
Biology				
• Introductory			1	1
• Population Biology	1	1	1	1
• Cell Biology (and Histology)	2	3	1	2
• Animal Science	4	3	4	4
• Plant Science	2	3	3	1
• Biochemistry	1	1	1	1
• Biometrics	1	1	1	1
• Ecology	2	2	1	1
• Microbiology	1	2	1	1
• Genetics	1	1	(incl. Evol.)	1
• Evolution	1	1	-	1
• System Physiology		1		1
• Neurology				
• Anatomy		1	1	1
• Molecular Biology			1	
• Embryology		1	1	
• Natural Sciences		1		
Total	26	28	23	28

* Courses vary in terms of hours per week (usually three to four) but they are all of one semester duration and some include laboratory work.

Source: Handouts/publications by the Universities.

The basic science courses are not necessarily geared toward the needs of the school curriculum and to some extent can be judged as either lacking in needed contents or as having contents pitched at a higher level than needed for the purpose of secondary school science teaching. Partly because of this situation, in the last five years there have been almost no physics or chemistry students who have chosen teacher training in these specialities (personal communication of head of science teacher training-programme).[10] The *Catholic University* of Valparaíso has a somewhat different structure in that all science teacher training is co-ordinated by the Science Institute. The *School of Education* at that university collaborates in the training process by providing pedagogical courses for teacher trainees, but preparation in science teaching methodology is located and administered from within the *Science Institute*. A concurrent pedagogical and discipline curriculum is in place and there is more opportunity to gear the course structure towards the needs of science teachers. The other two universities are quite different in that both of them (which were originally part of the University of Chile) are pedagogical universities whose main function is to train teachers.

While, in practice, their curriculum is not substantially different from those of the Catholic universities, structurally they do offer better possibilities for a relevant science teacher programme which is essentially of a concurrent nature; though the level at entry among students is qualitatively lower than among students in other traditional university programmes.

Consideration of the relationship between the science content in biology learned in these programmes and the school curriculum poses some questions. As seen in *Table 3* below, the biology programme in the 'science for all' curriculum is very much focused on issues relating to people, their health and their relationship to the environment. The elective units (for the science stream in upper secondary) follow this lead but with greater depth being given to plant and animal biology and to genetics and

10. This is because students who are successful in the basic sciences programme are eligible to continue on to more prestigious science career programmes, while those who from the beginning indicated their interest in teaching find the science contents difficult to master.

evolution. In the light of this curriculum, it would appear that teachers are being excessively prepared to teach in the science stream of upper secondary, and are not sufficiently prepared, for example, for the human biology aspects in the core curriculum. (see *Table 3*).

Table 3. Biology curriculum of Chilean secondary schools

Common Core Units			
Year 1	*Year 2*	*Year 3*	*Year 3*
1. Health Education. 2. Biological equilibrium in Nature.	1. Unity and diversity in the world (elements of cell biology, plant and animal sciences). 2. Exchanges of matter and energy between organisms and their environment (human physiology).	1. Systems of organic integration. (elements of neurology, anatomy, human physiology).	1. Reproduction and development of living beings. 2. Transmission of inherited characteristics.
		Elective Units	
		1. Cell biology (homeostasis) and plant organisms.	1. Animal organisms and basic elements of ecology. 2. Organic evolution and genetics.

Source: Revista de Education, 173, December 1989, pp. 13-41.

This discrepancy noted between school curriculum and science teacher training in the Chilean context illustrates the difficulties of negotiating, between the hard science advocates and the science educators, a training programme that is both sufficiently strong in its content that teachers master the science they have to teach over and above curriculum requirements, but at the same time is relevant to such school curriculum and its possible 'science for all' and 'technology' components. The situation is also illustrative of the deeper conflict existing today between the increasingly complex and abstract nature of the sciences and the growing trend towards universalization of education.

Sabrovsky (1992) in analysing the European situation in relation to the teaching of science, technology and society, notes deeper reasons why science education that is oriented to the logic of the sciences may be failing:

> *"Sciences in the twentieth century have abandoned their former links with common sense: with their n-dimensional spaces, their relativist and non-linear approach to time, etc., they point towards a fragmentation of experience that no longer is reducible to any one common denominator. This fragmentation, on the other hand, coincides with the trends towards mass contemporary societies (and especially of their educational systems), that in post-modern societies lead into a sort of irreducible heterogeneity of experience..."*[11] *Sabrovsky, 1992.*

> *"Given that it is only possible to teach what in some way or another is already prefigured in our daily experience, the abandonment by sciences of the arena of common experience necessarily translates itself into what we might call the 'crisis in the teaching of European science' which various educational reform movements have unsuccessfully endeavoured to overcome. Ultimately, this crisis becomes manifest in the (educational and social) system's inability to generate massive interest in the social importance of the sciences and in learning about them in this respect. It has also led to an 'objectivist' psychology of 'aptitudes' – labelling of the 'good' and 'bad' ones at maths – that blames the affected ones for their 'learning problems'; and allows a formalistic educational system to feel relieved of responsibility and thus legitimated"*[12] *(Lyotard, 1987).*

The corollary of an analysis such as the one quoted above is that there is some danger of distorting the learning of science that teachers need within the context of programmes which are solely scientific (such as given in a science degree followed by teacher-training pattern). Thus the structure of initial teacher training offered by consecutive models of structuring the content and pedagogy components of the curriculum may not offer the best sort of training arrangement (Gilbert, 1989). A number

11. Translated by B. Avalos.

12. Translated by B. Avalos.

of science degree or solely science-based initial cycles increasingly prepare students within the perspective of the science discipline and lack, as Sabrovsky indicates, the social radiance that science needs in a mass society and a mass education system.

Concurrent models on the other hand, if well articulated and well taught, are a means of bringing the pedagogue – the science and other educators – together with the scientist in a common effort to teach the concepts of science while also making sure that these relate to the conceptual frameworks students already have, as well as to the social problems that science is equipped to handle[13].

The need to find an appropriate structure that caters for science content and is appropriate to the social concerns of teaching is an important issue not only in Europe but even more so in other regions. University programmes that dichotomize science content and teacher-training experiences are also resulting in an alarming shortage especially of physics and chemistry teachers, as well as of general science teachers who are fully competent in their subject area.[14]

13. There are of course drawbacks: the quality level at entry may be lower than in the case of science degree students and also the quality of science teaching may be lower, especially in developing countries with less human resources available.

14. This was noted for countries such as Korea and Australia where school students (especially girls) tend to avoid the study of physics and where lack of appropirate integration between content and methods during pre-service training are affecting numbers and quality of trained physics teachers (UNESCO, 1988). This is also true of the post-graduate diploma in secondary teaching at the University of Papua New Guinea, which has very few science graduates who apply for teacher training, and also of the B.Ed. (Science) with a high percentage of failure among those taking science courses in a programme which to a large extent has also the 'consecutive' type of structure.

3.4 Pedagogical components

The theoretical approaches to science education noted in the first part of this monograph find their way into teacher-training curricula at a slower pace than that with which they are developed by theorists and researchers (cf. APEID/UNESCO, Bangkok, 1989), and once in they are difficult to alter as new evidence emerges. In the sixties and seventies, science teacher-training programmes were affected in many Latin American and Asian countries by the behavioural movement and the Nuffield Science's emphasis on skills and competencies for "process-oriented science education" (APEID/UNESCO, 1989). Thus, it was common that whenever they met as a body, science educators and teacher trainers drew up lists of the skills and competencies needed to produce teachers who could help learners develop skills for prediction, hypothesis formulation, observation, data recording, analysis and interpretation, all of which were considered crucial to understanding the investigative nature of science, but also as a means of gaining conceptual understanding. Today, with newer orientations emphasizing constructivist views of teaching and learning, the 'science for all' principles of curriculum construction and aims of scientific literacy, and science and technology, the wording of objectives is slowly beginning to change, as can be noted in more recent policy formulations (see *Box 4* below).

Box 4. Objectives of science teacher training in selected Asian countries

The curriculum changes and renewals in member countries have also resulted in perceptible changes in the objectives, structure and contents of science teacher preparation programmes. A broad overview would indicate that, generally speaking, the following are included in the objectives of teacher preparation programmes:

- develop an understanding of the nature of science and take a holistic view of science;
- acquire sound scientific literacy and appreciation of social and ethical aspects of science and technology;
- analyse the content in terms of concepts, activities and applications;
- plan suitable activities, mobilize appropriate resources, and organize activities;
- design, identify and implement strategies aimed at developing science process skills;
- relate learning experiences and learning activities to the development, design and organization of activities to help children with specific needs, i.e. slow learners, gifted, physically and mentally handicapped;
- encourage learner-centred and activity-based approaches;
- utilize learning experiences from life and immediate environment of the learners;
- develop suitable outlines, procedures and methods of evaluation and provide feedback for remedial action;
- identify real-life situations, solutions of which are undetermined and probably could be obtained by teacher and learner working together;
- improvize, handle and utilize low-cost teaching/learning aids to make the learning experiences and environment joyful;
- appreciate the use of educational technology and also encourage the children to utilize the same;
- familiarize himself with the curricular changes taking place and equip himself to act as interpreter of new ideas and technologies to the community;
- find out the relationship of science and technology with health, agriculture, industry, nutrition and other aspects of living;
- use the scientific knowledge in correcting false beliefs, prejudices and practices;
- develop decision-making and problem-solving skills and utilize these in daily life situations.

Source: APEID/UNESCO, 1991, pp. 31-32.

Chapter III

Major determinants of science teacher training – lessons from research

This chapter reviews relatively recent research that offers insights into the major determinants of science teachers' training. Though desirable it was not possible to examine more than a few items of research directly relevant to developing country contexts. Unfortunately, such research is either not publicly available or not up to date; although recent reviews in *Science Education* report on a few related studies in South Asia and Africa. What have been selected for this review, however, are studies from published sources that deal with issues which are of interest to this monograph and that present innovations that from the point of view of their purpose, activities and resources required, are relevant in the planning of innovatory experiences. Following the organizing framework in *Figure 3, Chapter II*, we shall refer to the research findings under four major headings related to:

- training procedures designed to modify student entry characteristics and prepare for teaching;
- in-service experiences aimed at affecting teachers' knowledge and teaching skills.

1. Effects of context, structure and content of science teacher training

1.1 Context: School system and culture influences

Ideally, research related to the context of teacher training should be able to offer information on the effect of arrangements regarding the system of education, the content of the science curriculum and teachers' guides, and of differing cultural influences over how the training process factors such as those imposed by the system of education and its science curriculum have an effect on how teachers are trained, few studies appear that specifically address the subject. Indirectly, however, two studies on curriculum and textbooks produced in different contexts, refer to contextual determinations over teacher training.

1.2 Science curriculum and teaching materials

Ross's (1993) recent analysis of Papua New Guinea's primary and lower secondary science curriculum materials, including the syllabus, teachers' guides and students' resource materials and work-sheets, throws light on what may be one source of the poor teaching quality of science teachers as documented in several studies (see Haihue, 1992; Waldrip; Giddings; Geoffrey, 1993). An important part of the training system to date has consisted in getting teachers to work with the materials provided, and classroom observation shows that in fact teachers stick very closely to such teaching materials (Haihue, 1992; Avalos; George, 1993).

A thorough content analysis of the materials leads Ross to conclude that the overall aims of the science curriculum, which correspond to the 'Science for All' perspective of science education, are at variance with the contents, approaches and implications contained in many of these materials. In order to gauge more precisely the implications for teaching and teacher training of the Papua New Guinea lower secondary curriculum, as examined by Ross, his descriptive summary statements are reproduced in *Box 6* below.

Box 6. What the secondary science curriculum materials in Papua New Guinea portray

On subject matter

The subject-matter appears to be a 'pot-pourri' of concepts from physics, chemistry and biology, with some coverage of geology, microbiology and traditional technology in the final grade. Course objectives include the development of cognitive, psychomotor and affective skills but the main focus is on the recall of information. Student activity is mainly through worksheets which in general require students to manipulate scientific apparatus, record observations and make low-level inference. The approach to problem solving is atomistic rather than holistic: students have little opportunity to plan or design investigations. Practical activity tends to follow a recipe approach designed to prove the point. There is some concern in the material for developing respect for traditional values but often this is expressed in cognitive terms or forced into situations where it does not really belong. ...

Although there is no obvious integrating theme for the course as a whole, there are linking concepts between subject areas. Biology is linked to chemistry mainly through the concept of chemical change; biology and physics are linked via the concept of energy and the particle theory; physics and chemistry are linked by the particle theory and energy. The level of abstraction in the physical science material is probably beyond the majority of students. Concept development is limited by the relatively rare use of every-day applications, by inappropriate illustrations and analogies, and by the lack of environmental focus of the activities. Biology and geology show more concern for every-day applications and the environment.

The most likely image of science promoted by this material is that science is about observing and describing things and explaining observations, following written instructions to perform activities with test tubes, electrical apparatus, burners etc. Its subject matter is drawn mainly from the realms of academic science and more rarely from the environment. Its chief concern is for the acquisition of facts and obtaining correct answers. In general the organization of subject matter reflects the needs of those who continue with a formal study of science rather than those for whom education is terminal, but the non-quantitative character of the course and its lack of depth may limit its relevance to upper secondary science. ...

On teaching, learning and communication method

Teachers' notes and worksheets comprise the bulk of information recorded in student exercise books. The course is heavily prescriptive – sometimes to the extent of prescribing the questions to ask of students. The syllabus advocates use of the 'discovery' approach but there are no explicit statements about what this means in practice. ...

Student activity is encouraged through the use of worksheets which generally emphasize manipulative skills, observation and reading comprehension. Results are communicated in the form of tables, diagrams, equations and, more rarely, graphs. The extent to which students develop skill in explaining their observations will depend on teacher skill in managing student activity. In general, the materials endorse a behaviourist view of learning rather than a constructivist one. Students' own perceptions of scientific phenomena are almost never exploited. The highly prescriptive 'recipe' worksheets seem more concerned with the verification of scientific theory than they are with enabling students to develop critical thinking skills.

Ross, 1993, pp. 206-209.

1.3 Textbooks and teacher knowledge

The links between teacher knowledge and reliance on textbooks, when such knowledge is insufficient, was studied by Gallagher (1991) who not only observed 27 teachers over a period of two years, but also examined the view of science presented by the textbooks they use. The texts, he found, are large volumes packed with scientific facts emphasizing more 'what we know' and much less of 'how we have come to know it'. That is, the view of science they present through print and illustrations is that of a solid body of knowledge with little attention to the processes by which scientific discoveries occur. Teachers being generally trained to use existing curricula and materials, it would not be far-fetched to indicate that such training is in fact influenced by the materials in use in the schools, instead of being the other way round; and that teachers are presented the same view of science as a body of factual knowledge as the books support. Few training programmes confront their pre-service teachers with alternative views through "courses in history, philosophy or sociology of science, or an advanced seminar on the nature of scientific knowledge".

1.4 Culture, knowledge and teaching

Culture is also a contextual factor that is related to learning how to teach science. Research on South Pacific cultures, for example, supports the notion that predominant cultural forms within Melanesian societies affect the perception of schooling and knowledge circulation in general and of science teaching in particular (Lindstrom, 1990; Waldrip; Giddings, 1993). Waldrip; Giddings' explanation for the very stereotyped form of teaching practices among lower secondary school teachers in Papua New Guinea, with little variation in the design and implementation of experiments, is that although this is partly the result of the prescriptive form of training received (also favoured in the curriculum materials, as seen in Ross (1993) above) it is also related to aspects of the Melanesian culture affirming that elders are from whom directions emanate, and that authority generally should not be questioned. Lindstrom (1990), who has been studying the forms of knowledge circulation among South Pacific cultures, holds that traditional production of knowledge "is not organized in terms of free intellectual inquiry" as one expects, for example, that science teaching and learning should be, but that on the contrary it is rigidly territorialized. And this applies in particular to the kind of knowledge that could affect understanding of science concepts: genealogy, origin myths, ritual aspects of technology, history and details of land tenure. These forms may well explain why in tertiary institutions in Papua New Guinea it is difficult to establish participatory, dialogue-oriented lecture environments.

Following the lead of those interested in examining the effects of culture in students' alternative conceptions about science, George (1989) refers to studies by George and Glasgow examining 'street science' in the Caribbean. Street science is the term used for "social customs and beliefs that deal with the same content areas that are dealt with in conventional science, but which sometimes offer different explanations to those offered in conventional science". Although George does not directly draw implications for teacher training of the existence of this 'street science' which involves both content and philosophical patterns, it is clear that they can be drawn in the sense either that student teachers will adhere to some of these concepts or that they will have to become aware that these concepts are held by their students and need to be considered in the processes by which conventional science is taught. The same author, in another article (1992), examines in fact how this street culture, and particularly cultural artifacts, can be used to sensitize practising teachers to the importance and value of traditional culture for the teaching of science.

1.5 The structure and content of science teacher training

Under this heading we consider those studies that have examined problems arising from particular structural arrangements and their effect on the quality of science teacher training, including the type of knowledge provided through specialized and pedagogic courses and activities. The section also considers evidence from research on the limitations of initial training, whatever the structural and content arrangements, as exemplified in the differences between novice and experienced teachers ('novices and experts').

(a) Consecutive and concurrent models of teacher training

Most programmes of secondary teacher training, especially for the upper grades, are of the consecutive type. That is, graduates from tertiary science courses subsequently go into a certificate, diploma or master's programme, generally of one year's duration, to receive preparation for teaching their subject. A number of studies refer either directly or indirectly to the difficulties inherent in these programmes in relation mostly to the kind of knowledge that the graduates exhibit when they begin their training programme (e.g. Gunstone, Slattery, Baird; Northfield, 1993). Gess-Newsome; Lederman (1993), for example, encouraged graduates coming into a teacher-training programme to examine their 'subject matter structures' (SMS), that is, their individual "conceptions and or organization of a specified area of knowledge" (in this case biology). What the subjects of the study discovered as they went through a year-long teacher-training programme and looked at changes in their knowledge structures, was that their prior science studies had exposed them to a set of disconnected topics and courses but not to an understanding, explicit or implicit, of the structure of biology. Student teachers recognized that they had never thought about biology in terms of their constituent topics nor of the relations between these topics.

Although students were able to recall the topics learned and represent them in various forms of diagrams (discrete, linear, hierarchical, web-like) these representations showed little evidence of connections between themes. In general, they tended to follow a linear approach to biology (similar to the content courses in their curriculum and in secondary school textbooks) starting with cell biology and ending with ecology and the source of this arrangement appeared to be, not so much what they had learned in science teacher-training courses, but the biology programmes they had followed in school and college.

Concurrent models can present similar problems to those of consecutive structures if control of the programme is in the hands of a science faculty and if students encounter education staff and courses after having completed a substantial portion of the programme requirements. Such a situation is described by Gallagher (1991) in relation to the Baccalaureate at the *University of Wisconsin*, where students who enrol in the science methods course after having completed 80 per cent of the programme requirements, notice a number of effects of this arrangement: (a) they do not have appropriate conceptual structures to aid in the interpretation of familiar phenomena in everybody's experience; (b) they have limited knowledge of the processes by which knowledge is generated and therefore find it difficult to plan a lesson which is meaningful to a learner and not just a set of explanations about 'a body of knowledge'; and (c) more specifically their knowledge of the historical development of science is insufficient to plan lessons that can help pupils to learn how scientific discoveries came about.

(b) The training curricula: courses and practice

Among the concerns about the effect of professional training (whether within consecutive or concurrent models), an important one has to do with the transfer of teaching skills and intellectual behaviours developed through course activities and microteaching experiences, into the longer practice teaching stage of training.

We consider two studies that have looked at problems associated with the 'practical components' of preparing teachers, within perspectives that could be applicable to any form of teacher training.

Microteaching and teaching practice: Microteaching is very much a focal point in science teacher training in that it allows students to learn how to plan and carry out a plan, to develop instructional skills and behaviours that are relevant to science teaching and to receive feedback on the quality of their teaching. But, as is well known, microteaching takes place in a somewhat artificial situation, where the student teacher is often confronted with his or her peers acting as pupils. Lederman; Gess-Newsome (1991) thus examined the extent to which skills and perceptions acquired during microteaching are used later during field experience or practicum and what changes are noticed at this point, both in skills as well as in concerns about teaching and learning.

Seventeen pre-service students were presented with open-ended questionnaires at the beginning and during each of the 15 weeks of the field experience, inquiring about their perceptions on skills (performance and improvement needs), on steps used in planning a lesson, on relevancy or irrelevancy for field teaching of skills learned or practised during microteaching, and what skills not learned in microteaching were developed and found useful. Answers from a random sample of six of the teachers' questionnaires were qualitatively analysed and compared, while other sources of information collected during the microteaching sessions and the field experience of these six teachers were also analysed (videotapes, peer critiques, course instructor and supervisor feedback, open-ended questionnaires during microteaching, and narratives from seminar discussions during microteaching and fieldwork).

The analysis focused on 'concerns' and their shifts from the microteaching to the classroom teaching situation. The researchers categorized 17 types of concerns and grouped them under the general headings of concerns for self and concerns for students. In general, the results indicated a growth in concern areas at the time of field teaching. Thus, for example, concerns in the areas of 'clerical/administrative skills' and 'work load' were new under the heading of concerns for self. Under concerns for students, there were also new areas ('motivation', 'rapport', 'depth and breadth of material' and 'time requirements for learning'). One of the interesting changes in the nature of concerns was in relation to 'planning'. While during microteaching, the writing of objectives was an important part of planning, this was not the case when they were actually teaching in the field; content and "the search for analogies, demonstrations, metaphors, stories, or activities to 'best' communicate the content" took precedence, while stipulating objectives became the last step of the planning exercise.

The conclusion reached by Lederman; Gess-Newsome was that all concerns about teaching awakened through microteaching remained and in fact were increased at the time of field teaching; but there was an important shift in the quality of these concerns from self to students (in agreement with results of many other similar studies). The problem of lack of time was noted as an important new area of concern: time to plan, time to learn and the diminished time effect of workload. The authors of the study concluded, that while microteaching had the effect of preparing students for the type of activities to be performed in actual teaching and awakening student concern about these, there were new concerns; in particular, the need for more time, that should be considered in planning the structure of the practicum. Pre-service teachers need time to work out their teaching strategies and to get to know their students' learning styles and problems, and therefore initially teaching responsibilities should be kept to a minimum. The other factor noticed was that these science/mathematics pre-service teachers were not primarily concerned about the content of their teaching; their concerns were primarily generic, a situation reflected in other research findings that indicate that novice teachers only worry about their subject teaching after they feel comfortable with classroom management routines.

Intellectual behaviours and length of teaching practice: The relationship between these two factors was the theme of Hacker's (1988) study of an Australian diploma in education course for science graduates. Citing Dreyfus; Eggleston's study in the seventies, in England, about the training of science teachers, Hacker sought to find out whether the same adverse effect on intellectual behaviour as teaching practice progressed, noted in the English study, was true of the Australian situation. Using the same observational instrument (*Science teaching observational schedule* developed by Egglestone) Hacker compared the teaching of two groups of student teachers that differed in the number of teaching practice blocks they had to engage in (two and three). In the interim between one period of practice and the other, students returned to the University where they continued their study and discussion of science education theory. The first group, with two periods of practice, lowered the display of higher-level intellectual behaviours in a similar way as the English students observed by Dreyfus and Egglestone, while the second group, with three periods of practice, actually increased this level. Hacker's interpretation of this finding was not that the longer practice was of itself better; but that the second group had more of an opportunity to reflect upon and improve its practice due to the closer integration between the practicum experience and the theoretical components of its pre-service education, while the first group had less of this. He also indicates that these results can be explained in terms of a model of professional development that needs to be considered in planning and evaluating practicum experiences:

- an exploratory phase, when students attempt a possible range of teaching approaches, some of which result from their recollections of science teaching at school and others which are learnt during the early stages of their pre-service preparation;
- authority-asserting phase, characterized by "interactions which are perceived as being 'safe' with respect to management and control issues"; this period has more teacher-directed interactions than pupil-directed behaviours;
- enrichment phase, where students use a wider range of teaching strategies and increase their intellectual behaviours.

Both the previous study of Gess-Newsome and this one by Hacker point to the same difficulty faced by pre-service teachers on teaching practice, regardless of the length of the practice: the need to become familiar first with routines of classroom management before they are able to focus on meaningful science teaching and use creatively the skills learned for this purpose. However, longer periods of practice in the same school and being exposed to the same teachers will not of itself improve the quality of this practice as the range of alternative teaching models remains the same. Hacker (1988) thus recommends a structure of multiple teaching practices, that integrate theoretical learning with the field experience:

> *"Perhaps, like their medical brethren, student teachers need opportunities to bury their mistakes! Integrated teaching practices may accelerate professional development by providing time for students to reflect on their strengths and weaknesses and make the requisite behavioural changes. A further possible advantage is that student teachers may be better able to apply the ideas presented in the theoretical component of their pre-service education when theory and practice are blended".* *Hacker, 1988.*

Table 4 summarizes the main results of the research reviewed hereafter and is aimed at facilitating the reading of this following section. The tables are arranged according to studies addressing the contextual factors that pose issues for or affect science teacher training, characteristics of pre-service teachers at the time of entry to a training programme, and effects of pre-service and in-service strategies in relation to training purposes.

Table 4. Context and structure: actual or potential effects on science teacher training

Context factors	Teacher-training issues
A. School system:	
• Lower Secondary science curriculum, texts, materials, teachers and pupils' guides. Papua New Guinea – Ross (1993).	Recipe approach 'to prove the point': • Little use of everyday applications of science. • Chief concerns: acquisition of facts and obtaining correct answers. • Little emphasis on student concepts.
• Science secondary textbooks. USA – Gallagher (1991).	• Emphasis on 'what we know', not 'how we know'.
B. Culture:	
• Melanesian Papua New Guinea – Waldrip; Giddens (1993).	• Authority/teaching relationship: directions emanate from elders – should not be questioned.
• Melanesian S. Pacific – Lindstrom (1990).	• Knowledge circulation rigidly territorialised – communication guarded in the face of strangers.
• Street science in the Caribbean George (1989).	Important to consider in the training of teachers if student prior concepts are to be acknowledged.

Table 4. (continued)

Contexts factors	Teacher-training issues
C. Structure of teacher training	
• Consecutive models (science degree followed by pedagogical training): Australia – (Gunstone, Slattery, Baird; Northfield, 1993) USA – (Gess-Newsome; Lederman, 1993).	• Quality of science knowledge: disconnected set of science topics – not appropriate for teaching general or integrated science or science for all.
• Concurrent Models but with large portion of science learning before pedagogical training, programme managed by Science department, not Education. USA – Gallagher (1991).	• Quality of science knowledge: Unclear conceptual structure and of scientific processes. • Lack of knowledge of history of science.
• Microteaching Effects USA – Ledermann; Gess-Newsome (1991).	• Transfer of concerns awakened in microteaching to teaching practice situation; • Change of focus: from self to student concerns; • New concerns: • managerial concerns prevail over content-specific ones.
• Blocks, length of teaching practice; interplay with learning/discussing theory Australia – Hacker (1988).	• Longer practice in one school: counterproductive for use of higher cognitive skills in teaching; but more shorter practice periods with opportunity for theory learning in between, more effective. • Above structure responds to three-phase development of teaching skills: exploratory authority-establishment and enrichment

Table 4. (continued)

Contexts factors	Teacher-training issues
D. Novices and experts – Initial training and continuing education	
• Training and experience: effects on expert science teachers. USA – Ost; Baird (1989).	• Over time, teachers attribute less of their classroom management skills (laboratory, storage of materials etc.), use of instructional materials and ability to carry out social purposes of education, to the influence of initial training.
• Cognitive patterns of beginning and experienced teachers. USA – Borko, Bellamy; Sanders (1992).	• Cognitive patterns (knowledge schemes, pedagogical reasoning and pedagogical content knowledge) – more complex and effective among experienced teachers. • Training only starts the process that experience continues.
• Mental abilities, content knowledge and procedural knowledge for problem solving – effect of different science training backgrounds and experience. USA – Barba; Rubba (1992).	• Experienced teacher have more content knowledge and better procedural knowledge. • Novices function at accretion stage of knowledge development; experts function at fine tuning stage.

2. Student teacher entry characteristics and teacher training

A considerable amount of research has indicated that teachers have concepts about teachers that resemble those of their students and suggests that training has not done much to change these (Gene; Gil referred to in Carvalho, Pessoa de, 1992; Hewson; Hewson, 1988). Based on the assumption that some student entry characteristics such as attitudes, beliefs and conceptualizations about science and teaching are alterable through training, it is useful to examine what some of the research concerned with these characteristics tells us. Earlier on, we made reference to studies that indicate that as far as views of science are concerned, school students are influenced by the images presented by textbooks and the messages conveyed by their own teachers, Gallagher (1991).

We consider here, other studies about student teachers that have examined the content of some of these views in relation to science, teaching and learning, and more specifically in relation to the importance of recognizing pupils' prior concepts, and therefore learning about ethnoscience in training. Also considered is research that looks at cognitive levels of student teachers at entry to teacher training.

2.1 Student teacher conceptions (concepts and beliefs) about science, teaching and learning

Aguirre, Haggerty; Linder (1990), following the lead of Hewson; Hewson (1987) developed a naturalistic, qualitative case-study in Canada designed to examine conceptions of student teachers about the nature of science, teaching and learning. Using a semi-structured questionnaire, 74 student teachers enrolled at the University of British Columbia's General Science Methods course were asked to write short statements describing their interpretation of science as a discipline and activity, and their views about the teaching and learning of science. Responses were examined, categorized and studied for distinctive characteristics and for an interpretative framework. Results indicated a number of different *conceptions* under each one of the headings of science, teaching and learning.

The *science* conceptions were of the following types: (a) naïve-science, or science seen as a body of knowledge that explains the 'why and how' of certain phenomena in the universe; (b) experimental-inductive, or science seen as a set of propositions proven to be correct; (c) experimental-falsificationist or science considered to be a body of propositions that have not been falsified; (d) technological-science, an activity aimed at technological advancement; (e) three-phase conception of scientific knowledge as the result of theory development, testing and acceptance by the scientific community. Both (d) and (e) were supplementary to the other main conceptions. Only four students held position (d) while more than 50 per cent held to what the authors consider are quasi-empiricist views of science (b and c) and 40 per cent held to the naïve view of science.

The *teaching* conceptions found referred to: (a) the teacher as source of knowledge and teaching as knowledge transfer, or (b) the teacher as guide and teaching as influence over understanding. Almost 50 per cent of the students held to the first view.

On *learning,* the categories found were the following: (a) learning as intake of knowledge (the mind as *tabula rasa*); (b) learning as trying to make sense of new information in terms of existing understanding; and (c) learning as an affective response in terms of stimulated interest or perceived need. About 50 per cent of the students held the view of learning as filling empty minds.

Of particular concern to the authors of this study was that so many students, despite their training in science, held to the naïve and the quasi-empiricist conceptions of science (experimental inductive and experimental-falsificationist). They also noted a connection between holding these views of science and believing that teaching is "knowledge transfer from the teacher's head and textbooks to the 'empty' minds of children".

2.2 Views about ethnoscience

Vlaardingerbroek (1990) surveyed secondary teacher-training student views about ethnoscience and its potential role in science education in Papua New Guinea. He asked students, through questionnaire and group discussion, what importance they gave to finding out about ethnoscientific beliefs held by school students and what attitudes they thought teachers should have regarding these views. Findings indicated token lip service to the importance of ethnoscience in schooling, and though some value was given to considering this knowledge when teaching, student teachers did not think this was of great relevance. In relation to their own views about ethnoscience, students did not see a conflict between these and Western science and could accept that they represent different spheres of influence and could support a dualistic conceptualization of reality. [However, they did not consider it appropriate to teach or recognize ethnoscience in schooling because it might 'confuse' students through competing with the new scientific models presented.] The author agrees with others who have studied the issue, that educated Papua New Guineans approve of the usefulness of Western science and consider that if the disappearance of ethnoscience is the price to be paid for 'progress', then so be it!

2.3 Intellectual ability levels

On levels of ability at the time of entry into teacher training the earlier review by Lanier; Little (1986) indicated that in the American situation there was evidence of a general decrease in levels of intellectual ability and teacher education had become less demanding; it was perceived as "easy and non-intellectual". This finding is probably true of many developing country contexts where teaching as a profession is undervalued in terms of salary and working conditions and therefore tends to be selected only as a last resort by school-leavers.

In relation to Papua New Guinea several studies have indicated low levels of science understanding in upper secondary students who constitute the potential population for science teacher training (Olney; Vlaardingerbroek, 1993; Boeha, 1990). In particular, and by means of a Piagetian reasoning test, investigated the entry characteristics of teacher trainees in one of the primary/lower secondary teacher-training colleges. Lake's study takes note of the fact that students in this college for the most part have only ten years of education and also that there exist important cultural factors that affect school learning. Application of the test by Shayer, 1979 to novice students with adjustments for cultural and linguistic differences indicated a spread around Piaget's concrete level with no novice students appearing to be using formal thought; however, a year later, after an intervention programme in science during their first year of teacher training, the situation was better, with a larger number of students found at the junction of concrete and formal thought; though only one (a mature student) was considered to be using formal thought. The author concluded that there is evidence to indicate that a suitable science course can help students progress to the level of their current competence as measured, for example, by the test indicated; but he also acknowledged that it is not clear how much cultural pressures may interact to affect this development.

Table 5 summarizes studies of characteristics student teachers have at entry, which should in turn be considered in the structuring of training programmes.

Table 5. Student teacher entry characteristics (concepts beliefs and ability levels)

Characteristics	Manifestations
Concepts and beliefs	
• About science, teaching and learning. USA – Aguirre, Haggerty; Linder (1990)	• Hold to quasi-empiricist and naïve views of science, not related to its uses in everyday life. • Both types of concepts and attitudes are related.
• About Ethnoscience and its role in science education. Papua New Guinea – Vlaardingerbroek (1990)	• Student teachers pay token lip service to it being taught in schools – but believe it might confuse students who learn Western science.
Ability levels	
• Level of science understanding at entry. Papua New Guinea – Lake (1991) and others	• Few students are at level of formal thought. • Suitable training programme produces some improvement.

3. The limitations of science initial teacher-training: differences between novices and experts

While much can be said of the importance of structure, content and procedures in the training of teachers, there is also the fact that pre-service teacher education is only one step in the development of a teacher, albeit an important one. In this respect, it is important to note research results that compare novice teachers with experienced ones, as they constitute an important source of information for the building of a theory of continued education. We refer to some of these studies below.

How teachers perceive the effects of training: One form of assessing the effect of teacher-training structures over the quality of teacher training is to ask practising teachers about their training and what they perceive to be the source of their knowledge and skills. The study by Ost and Baird (1989) asked experienced secondary teachers (in Alabama, USA) who had different levels of training, to present their perceptions. From the total set of responses (491) the researchers analysed separately those of science teachers (67). Although obviously related to the particular training contexts of these teachers, the results are of a more general nature and echo what is at least intuitively known in other situations.

The science teachers did not attribute a significant importance to their teacher-training programme in relation to management skills such as adjusting laboratory instruction to school day requirements, or to organizing time and space efficiently for the storage of materials, student movements etc.

Also, they believed that their knowledge and ability to use a variety of instructional materials such as films and laboratory materials was primarily the result of experience and not training; and that training was less important than 'other sources' for their ability to steer teaching to learner needs. Finally, their teacher education was not perceived as important in relation to social purposes of education such as working with multicultural groups or developing parent and community support for their particular teaching area. Compared to non-science teachers' views on the same subjects there were practically no differences in their lack of recognition of training as a source of their professional expertise.

In assessing these results, the authors note two possible interpretations. The obvious one is the suggestion of possible inadequacies in the undergraduate and teacher-training programmes experienced by the teachers in this study (but these were of two different types and generally both with a high level of requirements). The other, for which the authors quote Wilson; Shulman, focuses on the process of growth that teachers experience over time. Initially, teachers are concerned with overcoming managerial difficulties through the use of knowledge and very basic skills learned in training; but as they gain experience, pupils' learning and response to their needs becomes a main concern and there is a great deal of thinking and experimenting and altering of initial practices through experience.

Thus, as teachers move to a stage of greater experience, they attribute their performance more to such experience than they do to initial or even in-service training. Seen from this perspective then:

> *"...the value of professional training lies in its ability to establish the need to know. ... Thus, with the exception of specifically identified behaviours, which can be tied to specific pre-service or in-service education, a teacher's perception of the source of knowledge and skills is associated with his/her experience".* *Ost; Baird, 1989.*

Cognitive patterns of novice and experienced teachers: Pursuing this theme of the differences between expert and novice teachers, and therefore the nature of what initial teacher training is able to do, we refer to the study by Borko, Bellamy; Sanders (1992).

The authors supported their study on the notion that teachers have a complex pattern of cognitive skills which include knowledge structures or 'schema' (knowledge of the teaching subject area), 'pedagogical reasoning' patterns and 'pedagogical content knowledge'. These concepts were described as follows:

- *Schema*: abstract knowledge structure that summarizes information about many particular cases and the relationships among them. ...

- *Pedagogical reasoning*: the process of transforming subject matter knowledge "into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by the students" (Shulman, 1987, p. 15).
- *Pedagogical content knowledge*: or "knowledge of subject matter for teaching, including the most regularly taught topics, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations – in a word, the ways of representing the subject that make it comprehensible to others. ... [It] also includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to learning" (Shulman, 1987, p. 9).

By looking at a group of four science student teachers and four classroom teachers under whom the student teachers were placed for practice, the authors of the study examined the differences in planning, teaching and post-lesson reflections of both groups of teachers and how these related to their cognitive skills. Data was collected through observation during a single science class each day for a week and through initial post-lesson interviews to determine planning and reflective patterns. The classroom observations centred on instructional activities, classroom routines and teacher instructional and management strategies. The main findings relating to the differences between expert and novices are noted in *Box 7.*

A similar study by Barba; Rubba (1992) but focused on earth and space science teachers compared 30 in-service and 30 pre-service teachers on their general mental abilities, their content knowledge and the procedural knowledge used in solving earth and space science problems.

The 'expert' science teachers were university graduates who had taken a certain number of courses in earth and space sciences, were teaching the subject in schools and had at least three years of teaching experience. The 'novices' had less university training in the subject than the experts and no teaching experience.

Box 7. Differences between novice and expert science teachers

Novices	*Experts*
None revealed clear, well developed beliefs about teaching and learning during the data collection time. Their planning was very detailed and time-consuming. Pedagogical thinking and actions differed across student teachers: • One teacher felt weaknesses in teaching were due to lack of knowledge and experience; • Another teacher with very strong subject background showed limited pedagogical knowledge and pedagogical content knowledge. He prepared detailed plans before each lesson, but rarely used these. He relied heavily on text during lessons. Spent little time interacting with whole class. Cognitive schemata are less elaborate, interconnected and accessible than those of experts. Schemata often have to be developed or modified as they plan.	Drew upon their pedagogical content knowledge, beliefs and experience in planning and teaching. Knew several ways of presenting lesson content. Had strategies for keeping track of activities from year to year, a notebook of factual material, and plan books with annotations. Did little or no written planning other than prepare monthly or weekly schedules of topics and assignments. Were skillful at drawing connections between classroom activities and students' lives. Could skillfully combine demonstrations and explanations into presentations that seemed to guide students to intended outcomes. They involved students in these presentations, controlling the direction of the discussion by acknowledging some responses and not others and by elaborating on those acknowledged. Laboratory exercises comprised a major part of science teaching in keeping with their pedagogical content knowledge. The exercises emphasized areas where students had previously encountered difficulties; and teachers moved from group to monitor and assist. Many questions were procedural in nature but some attempted to extend students' content knowledge and conceptual understanding. Teachers' post-lesson reflections focused on students, and drew comparison between observed lesson and previous experience teaching the same content.

Results from the comparison between the groups on mental abilities and declarative knowledge showed significant differences. Expert teachers had more knowledge of their domain than did novice teachers (also found in other studies). The groups also differed significantly in their structuring of declarative knowledge (i.e. concept understanding and use of rules/

principles and problem solving) with experts having better formed cognitive structures. Using the transcripts from the interview session the nature of the differences between pre-service and in-service teachers' declarative and problem-solving knowledge was examined. In terms of sheer quantity, it was apparent that expert teachers verbalized more content knowledge than pre-service teachers. In relation to problem-solving abilities expert teachers tended to use fewer steps towards the solution of a problem than did novice teachers.

In explaining the above results, the authors referred to the fact that the pre-service teachers in the study had insufficient content knowledge for the curricular contents they were asked to teach.

But also the observed differences with experienced teachers in levels of structural knowledge (use of concepts, rules/principles and problem-solving procedures) may be the result of novices functioning still at the 'accretion' stage of mental activity (adding new knowledge to existing schemata) as opposed to the experts who had moved past the stage of forming new conceptual structures and were functioning within the 'tuning' or fine adjustment mode of knowledge.

Both the studies by Borko, Bellamy; Sanders (1992) and by Barba; Rubba (1992) deal with novice and experienced teacher cognitive structures, suggesting that pre-service training may not be fully able to develop these in relation to appropriate teaching requirements; the studies thus strengthen the case for research that not only in industrialized countries but also in other contexts is able to point to the most favourable forms for initiating what is obviously a longer process of development of knowledge and skills for teaching. The evidence also indicates, as Borko, Bellamy; Sanders suggest, the need for longitudinal studies of teachers as they move from the initial to the experienced stages of teaching.

4. The continuing education of science teachers: novices and experts

It is generally argued that the provision of in-service opportunities for teachers is needed because of the knowledge explosion and because of curriculum changes that require teachers to be up-graded in these respects. While it is a good argument for having a well-organized programme of in-service training, perhaps a deeper reason is that learning to teach and mastery in teaching are a function of time and experience coupled with support from colleagues and professionals, a factor highlighted in a number of research pieces focusing on the differences between novice and experienced teachers (to be examined more extensively in the next chapter). It is, therefore, important to consider that growth in the profession requires a variety of life experiences in a teaching career. These experiences can be structured for different purposes. They include the widening of the knowledge base of teachers who have limited qualifications either in science or in other fields. An example is structured in-service degree programmes, often sponsored by national governments, as is the case, for example, of Papua New Guinea.

Other purposes are related to improvement in strategies for teaching science, to growth in the understanding of science concepts already encountered at some stage of previous training, to acquaintance with and use of recently developed curricula and science materials, or to stimulate teachers themselves towards being innovative and able to create new strategies for teaching.

The different purposes of in-service education within the context of different country and individual needs are best served by having a variety of experiences available. These may range from school-based workshops to regional or national/international information-giving experiences. They may include academic programmes aimed at providing teachers with the 'official' qualifications needed to teach or with a higher level of subject/pedagogical knowledge. Collaborative activities between teacher-training institutions and school teachers are proving to have enormous potential for professional growth of teachers.

A special comment needs to be made regarding the experience and potential of distance in-service activities to reach teachers who would otherwise find it difficult to get to centres offering specific up-grading courses. Much has been said of the value of distance education for the training and up-grading of teachers situated where the cost of full-time programmes for the many needing training would be very high.[15] There is need for some caution, however, when it comes to science because of the requirements of practical work and because also of the need to provide materials that are both conceptually adequate while at the same time attractive and paced according to learner needs. This may require a greater variety of materials of an audio-visual type than currently provided in programmes such as those at the University of Papua New Guinea (John, 1991) and investments in electronic equipment, satellite communication link-ups that enable, for example, telephone conversation between students and tutors in remote regions, as exists in the University of the South Pacific, which has a strong in-service distance programme. Given care in the preparation of materials, and investments in communication networks, then it is possible to say that distance education offers an excellent opportunity for developing a variety of programmes that service teachers both in their knowledge and teaching strategy needs.

Within the variety of in-service programmes that may be offered (see *Box 8* for examples), issues regarding orientation and procedures are as important as they are for initial teacher training. In the planning and conduct of in-service activities, the 'pedagogical knowledge' framework of teachers (existing conceptualizations about subject-matter and teaching) has to be acknowledged as the building block for new experiences. Also, more so perhaps than in initial training, the purpose of an in-service activity will be better served by procedures that move closer to the open-end of the continuum (in *Figure 1*), that is, which are embedded in a symmetrical relationship of trainer and trainee focused on the process of change. This change, as Baird (1988) indicates, "requires appropriate experiences, opportunities for the teacher to reflect on practice, and protracted support for the teacher during the uncertain and disequilibrating change process".

15. For example, Nielsen; Tatto (1991) note that distance teacher training in Indonesia is less expensive than conventional programmes, but students have to bear a relatively high portion of the cost of the programme. Compared to those campus-based, distance programmes in mathematics were more effective in conveying knowledge and concepts than in conveying practical and computational skills.

Box 8. Types of in-service physics programmes in selected Asian countries

Philippines: Summer Science institutes at the regional Sciences Teaching Centres, also at the University of the Philippines (6 weeks). Volunteer Training Programme for beginning non-major physics teachers conducted by volunteer trainers from high schools and teacher-training institutions.

Sri Lanka: Conducted by the Physics and Science Committees in the Curriculum Development Centre and Regional Centres, courses to upgrade in content as well as physics teaching methodology.

Papua New Guinea: National in-service training for one week for physics teachers in their provinces.

Nepal: Science Education Development Centre – three-month refresher intensive training and one to four-week training for teachers. Emphasis on content upgrading and updating, activity-based teaching, utilization of local resources, and motivation.

Thailand: Upper secondary physics teachers trained for 10 days: inquiry and activity-based approaches, workshops on test construction, use of microcomputers in physics teaching, and building/repairing of physics apparatus.

Pakistan: Master trainer programmes conducted for one to two weeks.

Indonesia: *Pemantapan Kerja Guru* ('strengthening the work of the teacher') programme aimed at changing teachers from a teacher-centred to a pupil-centred approach; two-week off-service activity followed by six-week on-service period. Teachers meet every Saturday during the on-service to share experiences and make detailed preparations of work for next week.

Source: UNESCO, 1986.

In Asia, an APEID/UNESCO (1991) organized workshop analysed requirements of science and technology teacher training in relation to general scientific-technological developments and to the aspiration towards further industrialization of South-East Asian countries.

For in-service activities emphasis was laid on the importance of support institutions such as teacher resource centres at provincial or district level. A three-tier model of in-service training (similar to the Indonesian one outlined in *Chapter V*) was suggested as one among other alternatives: (i) selection and preparation of key persons as Master Trainers; (ii) training of resource persons; and subsequent (iii) training of teachers.

The Seminar produced also a set of materials exemplifying procedures to evaluate the competencies and skills of practising teachers and teacher trainees, a sample of which is included in the *Appendix*.

5. Summary and lessons for science teaching gleaned from research

First of all, what stands out from the preceding analysis of research and from *Table 4* is that *context* factors such as science concepts and approaches found in curriculum, textbooks and syllabus may have an effect on the concepts about science teaching of teacher trainees and are important to be considered when training science teachers to use these materials.

Equally, cultural factors may affect science teacher training in at least two different ways (Erickson, 1986): in the conceptions about science that students bring from their environment (different in the Caribbean, or among the Indian communities in the South American *Altiplano*, or in the various ethnic groups in the South Pacific countries, Melanesian or other, or the language and ethnic groups in the South Asian countries), as well as in the ways of interpreting the nature of authority and of teacher/student relations and the forms by which knowledge may be circulated.

The form of *structuring teacher training* in turn affects both the quality of science knowledge imparted to a novice teacher as well as the quality of his or her 'knowledge for teaching' (pedagogical content knowledge). Also, the practical components of training may not be the most adequate if they simply involve teaching in one place for too long, or if they carry heavy teaching loads. Shorter blocks of training combined with reflection-on-practice and theory learning may be more effective.

In general, therefore, it is important to examine what arrangements can be made in the formal structure and contents of the training programme itself to reduce the ill effects of too much or irrelevant science learned in undergraduate study and prepare for meaningful classroom teaching.

Most important are the real limitations of initial teacher training no matter how well structured or developed it is. Of itself, initial teacher training cannot produce a fully-fledged teacher and only experience, coupled with programmes for professional growth, can really aid the teacher in her process of becoming an 'expert'.

Chapter IV

Changing science teaching through training: experiments and initiatives

Although teacher-training research continues to be influenced by the behavioural approach, requiring attention to skills and strategy development, to a certain extent, recent research focusing on teacher-training processes as a whole and conducted within the framework of constructivism and of 'reflective teaching', is becoming predominant. This research is based on the assumption that comprehensive overhauling of teacher-training procedures is a better means of assisting pre-service teachers to understand the science curriculum and how to teach it from the perspective of learners, and that science education requires processes that have a strong component of student teacher reflection-in-action. Reference is made therefore to studies centred on teaching skill and strategy changes and those involving holistic reorganization of the training programme.

The results of research on skill and strategy changes through pre-service teacher training are summarized in *Table 6* hereafter.

1. Teaching skill and strategy changes

1.1 Process-product research evidence

An earlier review by Yeany; Padilla (1986) examined 'process-product' research on the effects of different training strategies in the development of particular skills (i.e. types of questioning, acceptance of student responses, appropriate waiting-time) among pre- and in-service science teachers.

Table 6. Skills and strategy change through training: pre-service level

Training objectives	Strategies	Outcomes
Teaching behaviours:		
• Questioning. • Accept student responses. • Appropriate wait time. USA – Yeany; Padilla review (1986)	• Variety of strategies: observation, modelling, practice through micro teaching, lesson analysis, peer/ supervisor feedback, reteaching.	• Most effective strategies are those that involve reflective analysis and feedback, besides all others.
• Problem-solving in physics. England and Spain – Garrett; Satterly (1990)	• 4-day seminar with activities to produce awareness of usual difficulties and what is involved in problem-solving; to lead to decisions on how to solve problems (steps) and to solve them adequately.	• Qualitative improvement in the procedures to solve problems (hypothesis formulation, interpretation and checking of results).
Laboratory teaching:		
• Practical tools for improving on failures in current laboratory instruction. Israel – Tamir (1989)	• Content analysis form. • Use of manual on lab instruction. • Dreyfus indicators of difficulty levels. • Concept maps. • Practical laboratory tests for: (a) design skills; (b) process skills.	• Effective tools for the assessment of laboratory experiments and pupil learning.

Table 6. (continued)

Training objectives	Strategies	Outcomes
Conceptual structure and science knowledge:		
USA – Mason (1992)	Seminar, using student-centred activities and concept maps.	• Progress form linear maps with limited connections, to maps with clearer representation and cross links.
• Subject-matter structure (biology) USA – Gess-Newsome; Ledermann (1993)	• Free graphical representation of subject matter structure, at beginning, middle and end of course on science methods and strategy; and later during teaching practice.	• Evidence of entry level misconceptions, and knowledge flaws from undergraduate science. • Pre-service teachers critique of science textbooks. • Improved understanding of pupil learning styles. • Change in conceptual understanding, improved subject-matter structure and 'pedagogical knowledge'. • New topics of 'science for all type' added to subject-matter structure.
• Understanding of nature of science and change in attitudes to science. Nigeria – Akindehin (1987)	Instructional package for twelve-week course: lectures, discussions, and class experiments (chemistry, biology and physics) with emphasis on process skills.	• Improvement of attitudes to: 'scientific inquiry', attitudes involving 'enjoyment of science lessons' and 'leisure interest in science'.

Table 6. (continued)

Training objectives	Strategies	Outcomes
Reflective teaching		
• Reconceptualising taken-for-granted educational practices. USA – Trumbull; Slack (1991)	• Seminar for science majors, centred on analysis of *interviews about instances.* • Student teacher written portfolios with interviews and reflections on these.	• Students developed new insights about knowing, teaching and learning biology; identified practices that interfere with learning, and became aware that performance needs to be seen from more than one perspective.
• Effective and reflective teaching practice. Canada – Erickson; MacKinnon (1991)	• Supervisory conference with supervisor modelling, discussing and practising strategies to exemplify constructivist teaching: 'showing and telling'.	• Student teacher reflection on teaching encounters and interpretation in accordance with reconstructed concepts of teaching and learning science.

For the analysis and interpretation of the research results, the authors used an analytical model that identified a hierarchical set of strategies ordered from the less to the more complex:

(a) study [by student teachers] of a behaviour analysis instrument (with clearly defined teacher behaviours) and learning how to use it;
(b) use of models of lessons for student teacher observation or for analysis using a behaviour analysis instrument;
(c) practice of teaching skills through microteaching;
(d) analysis of lessons, whether self-analysis (with appropriate instrument), peer feedback or supervisor feedback;
(e) reteaching using skills or procedures found inadequate through previous analysis.

A meta-analysis integrating the results of this research showed that training in all of the strategy levels had a positive effect on the behaviour of the science teachers involved; however, the magnitude of the effect was greater in those strategies that, in addition to the lower level strategies, also involved analysis and feedback. The authors' conclusion from the review was that the "more formalized the training becomes (by the use of models, behaviour analysis systems and the employment of self, peer, and supervisor feedback) the greater the effect on teacher behaviour".

1.2 Problem solving

A four-day seminar activity to train in problem solving was conducted with pre-service science teachers in England and Spain (Garrett; Satterly, 1990). The rationale for the seminar was that teachers in pre-service training usually view the solution of physics problems as the paper-and-pencil type of exercises presented in textbooks, neglecting the scientific approach to problem solving that requires thinking and the formulation of hypotheses for their solution. To alter these views and strategies the seminar aimed at stimulating its participants (a) to question the usual forms of teaching to solve problems; (b) to consider what is involved in the solution of a problem and contrast this by the concept of problem and solution found in textbooks and teaching; (c) to consider practical steps that could lead to the solution of a problem; and (d) to solve problems as a form of investigation.

The effects of the learning in this seminar were evaluated by means of a pre-test/post-test experimental design involving the English and Spanish pre-service teachers having participated in the seminar and a group of non-participating pre-service teachers from each country.

Results of the pre-tests showed no significant difference between the groups in that both held the concept that paper-and-pencil tests were simple, closed exercises about which they had little to criticize. After the seminar, the post-tests indicated a qualitatively different approach to the solving of problems characterizing the seminar participants which was particularly marked in the hypothesis formation and the interpretation and checking of results. The seminar also proved valuable in altering the students' opinion, from the perspective of what they had experienced in the seminar, about the value of problems for teaching.

1.3 Laboratory teaching

The criticism of the excessive emphasis on process of laboratory teaching in science education has led to different attempts to rethink its role and to provide new perspectives on how this teaching could be used more appropriately in the context of 'science for all' educational objectives, rather than as training pupils to become mini-investigators. One of the methods suggested is that the laboratory could be less reliant on the "doing of experiments" and more on the "discussing and evaluating of experimental outcomes" (Millar, 1987). In other words, experiments that do not work would have as much value as experiments that do work, the central concern being to discuss illustrative elements of a scientific paradigm as embodied in an experiment.

Seeking to rehabilitate laboratory teaching as "the most distinctive feature of science instruction", Tamir (1989) presents a number of practical forms by which to redress some of the failures noted in laboratory instruction suggesting in particular as (i) the use of content analysis forms to see the degree of guidance or openness allowed by the experiments; (ii) the training of pre-service and in-service teachers in how to teach the concepts that underlie laboratory instruction; (iii) organization of laboratory activities according to difficulty levels, so that a same laboratory exercise may have different versions according to difficulty level.

1.4 Subject matter structure (SMS) and concept mapping

Two studies are reported below that deal with procedures destined to help pre-service science teachers evaluate the nature of their science knowledge and of changes that occur in their conceptual structures as a result of training.

Concept maps: Mason (1992) describes a training programme aimed at enabling student teachers to examine their science knowledge and conceptual structures that included the use of 'concept maps'. Grounded on Shulman's model of *Pedagogical reasoning and action* and focused on content-specific teaching and learning, concepts such as evolution, ecology, genetics and respiration were used for discussion and as bases for the maps.

Through their development of concept maps and of comments on each other's schemes, it was expected that students would understand the nature of concepts and their interrelatedness, identify their prior knowledge and misconceptions, notice individual differences in learning style, learn how to ask questions and engage in meaningful learning.

The main findings of the study indicated that student maps evolved from linear forms of representation with somewhat limited connections to concept maps with a clearer hierarchical representation and cross links. Misconceptions and indications of the somewhat fragmented undergraduate science education became evident. As they progressed through the course, it was reported that student teachers became amazed at the encyclopedic character of science textbooks. They felt that curricula should lead to "a deeper conceptual understanding of fewer aspects of science". They were also able to understand that learners have a variety of learning styles and as the semester progressed, students became more able to organize the science they knew for the purposes of teaching students.

Subject matter structures: Gess-Newsome; Lederman's (1993) study on the quality of biology knowledge of pre-service secondary teachers used a related form of methodology to that of concept maps to examine knowledge structures of student teachers.

In order to learn about the student teachers' Subject Matter Structure (SMS) students were asked at the beginning of their Science Methods and Strategy course to remind themselves of the main topics contained in biology, their primary teaching content area, to write these out and to draw a diagram representing these content areas. They were also asked to consider whether they had ever before thought of their content area in this way. Five weeks after and then at the end of the course, student teachers were again asked to describe the topics of their content area and whether their views had changed in relation to their first description.

A second phase of the research consisted in assessing possible changes in the SMSs as the student teachers engaged in their practicum experience. The teachers were asked to describe again their content area and to participate in a 30-minute videotaped interview with one of the researchers.

The main findings of the research indicated that through this approach student teachers were not only improving their growth in what has been described earlier as 'pedagogical content knowledge'. But also increasing the number of terms considered as part of their science knowledge structure. New topics were added, for example "issues related to the nature of science, relevancy of science to students' lives, and STS (Science, Technology, Society) interactions".

Instructional package: Also with the aim of developing in student teachers an understanding of the nature of science and to produce changes in attitudes to science, Akindehin (1988) reported on the effect of an instructional package developed in Nigeria. The package, described as an *Introductory science teacher education* activity, comprised lectures, class discussions and laboratory practical work of one hour per week during twelve weeks.

The evaluation of this experiment indicated significantly different results in favour of the groups exposed to the instructional package in the understanding of the nature of science, and in three out of four sets of scientific attitudes: to 'scientific inquiry', 'enjoyment of science lessons' and 'leisure interest in science'. The last two groups of attitudes, as can be noted, respond to the 'science for all' types of outcomes which are expected of science education.

1.5 Reflective teaching

The role of reflective activities in teacher training is an important theme, as noted already in many of the studies reviewed above. Other studies specifically address the development of analytical reflection about personal beliefs, attitudes and knowledge. Their conclusions are summarized in *Table 6.*

The main results of these programmes of a more comprehensive nature are presented in *Table 6* too.

2. Comprehensive innovatory strategies in teacher education programmes

Turning to experimental arrangements during teacher training, aimed at widening the science education content received in undergraduate specialized science courses, the following set of studies report on comprehensive strategies aimed at changes in pre-service science and pedagogical knowledge structures, attitudes and the development of appropriate teaching strategies. (See: Summary of comprehensive strategies (*Table 7*).

2.1 'Preparation for teaching' course at Monash University in Australia

The one-year teacher-training programme for science graduates at Monash University has functioned for over ten years through an institutional arrangement of seminar groups and activities structured within the context of a course titled 'Preparation for Teaching' (that takes place seven weeks before the initial three-week teaching practice). During this course pre-service students are organized in mixed seminar groups (of chemistry, biology, physics specializations) except for activities relating to special subject methods. The activities within the 'Preparation for Teaching' course (as reported by Baird, Fensham, Gunstone; White, reviewed in Baker, 1991, and Gunstone, Slattery, Baird; Northfield, 1993) are:

> *"... designed to build confidence and knowledge about themselves [students] (e.g. video replay of their teaching of peers, reviewed by peers in a very supportive atmosphere) and gain confidence and experience in working with pupils [e.g. teaching one pupil; working with very responsive primary (elementary) students]. Considerable time is given to reflection, both oral and written, on these experiences. In these reflections self, task, and impact concerns are often inextricably connected".*

The focus of the programme is a 'constructivist' one in which students' views about teaching and learning, their understanding of the content they must teach, and their views of self are of importance. Improvement of the students' teachers' understanding of subject content is pursued through a series of minicourses on unfamiliar science areas and skills; for example, physics for non-physicists, microbiology, solar energy, establishing and maintaining an aquarium (Gunstone, Slattery, Baird; Northfield, 1993). Attention to scientific alternative conceptions in their areas of specialization is carefully developed through the experience of constructivist teaching and the opportunity to examine their own views of teaching and learning, their science concepts and their attitudes to science education. Learning about the tools for teaching is covered by following the principle of 'modelling rather than mimicking' (as in personally using, for example, concept maps rather than learning how to use them with pupils).

The researchers examined closely the data relative to four cases and their progress through the year of training. The most important finding in the eyes of the researchers, was the "nature and extent of personal development experienced by many of the participants".

Table 7. Comprehensive change strategies: pre-service level

Training objectives	Strategies	Outcomes
• Exploration of concepts and attitudes about science teaching and learning; improvement of subject content and skills of teaching. Australia – Baird, Fensham, Gunstone; White (1991)	• One year course organized in seminars with students of all science specializations. • Videos-replays-discussions. • Minicourses on unfamiliar science topics. • Modelling alternative strategies. • Research/evaluation strategies, interviews, diaries.	During training: • Changes: intellectual competence, task-related competencies and affective change (personal satisfaction) • In different ways during the year, depending on intellectual competence and self-perception. Induction year: • Increase in professional satisfaction and reflective capacity.
• Stimulate student teachers to adopt constructivist approach to teaching and learning physics. Portugal – Thomaz; Gilbert (1991)	• Training changes based on implementation model with 5 stages: 4th yr. of 5yr. B.Ed. structure: • *Awareness:* Individual writing and group discussion on physics learning and teaching – presentation of alternative teaching models. • *Interest:* Working out of aims for physics teaching from constructivist outlook – group discussion on this. • *Trial and evaluation:* Action research through planning and implementation of lesson, teaching activities to elicit pupil concept understanding. 5th yr, teaching practice and induction yr. • *Adoption*	• Increase in self-awareness about students' own alternative conceptions about physics; identification of skills and processes to aid pupil understanding; awareness of limitation in teaching process skills. • Different levels of adoption of constructivist teaching. • All, to greater or lesser extent taught using constructivist principles. • Success dependent on context (support, resources), teacher educators support, willingness of teachers to challenge students

In one sense, this meant development in specific intellectual competence, very much linked to the teaching of science content and expressed in task-related competencies; but there was also a strong affective component of their development, due to the satisfaction of experiencing growth in self-knowledge and reflective capacity and a greater feeling of self-confidence. Both aspects, the specific cognitive and task-competencies and the affective outcomes, are considered to be fundamental to a teacher education programme.

After completing their teacher training, students were followed in their induction year in the field. At that point novice teachers and their school students became part of the research team. It was found that the teachers' professional satisfaction increased and so did their reflective capacity. Also, while the school students became more responsible for their own learning, the teachers became "more perceptive, resourceful classroom practitioners" (Baker, 1991).

2.2 *Revamping of a secondary physics teacher-training programme in Portugal*

The programme developed and evaluated by Thomaz; Gilbert (1989) represents a comprehensive attempt to modify the approach, structure and strategies of secondary physics teacher training in one Portuguese institution, within the framework of a constructivist perspective and following a specific change model. On the premise that in-coming students to teacher training would have a restricted view of teaching and learning and that they would have to examine the physics concepts acquired through undergraduate training, the training scheme was developed to stimulate student teachers to adopt a constructivist approach to the teaching and learning of secondary school physics. The implementation model selected (Rogers, in Thomas; Gilbert, 1989) consisted of the following five stages: (i) awareness; (ii) interest; (iii) trial; (iv) evaluation; (v) adoption.

The scheme was designed to operate during the last two years of the degree programme and the year after graduation. The stages of 'awareness', 'interest', 'trial' and 'evaluation' of the model were pursued in the Teacher Formative (Year 4) phase by means of a seven hours per week course for 15 weeks. The *adoption* phase of the programme took place in year 5 during the Teaching Practice period. A maximum of six student-teachers was allocated to a school and supported by a team of four supervisors (a school teacher, and chemistry, physics and education tutors).

The general conclusion of Thomaz; Gilbert (1989) regarding the innovation was that it had varying degrees of success in the Portugal context that depended on contextual conditions such as sufficient quality time to enable students to change their attitudes and develop new skills; the availability of required support resources such as discussion material; early recognition that student teachers might not have a good understanding of science concepts or enough skills for conducting discussion; a good rapport between student teacher and teacher educator and adequate support during teaching practice and induction; and finally, the willingness of students to challenge the conservatism of pupils and convince them of the worth of the innovation.

3. In-service education

A considerable amount of research has centred around the effect of in-service activities on changes in teacher attitudes, knowledge and teaching styles. We include here a sample of evaluations of workshop activities, master training, and effects of collaboration between academics and teachers in changing teacher performance. The approach of the studies also reflect conceptions of teacher training that either rely more on discrete skill improvement (represented generally in the small-scale in-service activity) or on constructivist and reflective teaching.

3.1 Short-term in-service activities

Koballa, Crawley; Shipley (1990) reviewed various studies that examined the effects of short-term in-service programmes in the United States (Summer Institutes) on changes in participant teachers and their students. Among the literature reviewed a study by Zielinski; Bernardo (in Baker, 1991) examined in particular the effects of a 10-day summer workshop for secondary teachers on their attitudes, concerns and knowledge about science, technology and society concepts. After the workshop the teachers prepared for their students a 10-day Science, Technology and Society (STS) unit. Data on the teachers' attitudes, concerns and knowledge was collected before and after the workshop. Equally, their students and a control group were tested before and after the unit on STS took place. Results indicated that as a result of the workshop, teachers reduced their concerns about teaching STS and increased their knowledge of it. Their students also showed a higher level of positive attitudes towards the subject and scored 13 points higher than the control group in knowledge of STS concepts.

3.2 *Long-term in-service programmes*

In contrast to the above studies, Abell; Pizzini (1992) reported on an extended eight month in-service programme for middle-school teachers in the USA, designed to increase their content and pedagogical knowledge. The programme consisted in exposing teachers to a problem-solving model which when used in classrooms should encourage science students to ask questions and find answers through investigation. The activities of the in-service programme were the following:

(i) A half-day awareness conference and four evening seminars designed to create what the authors call a 'cognitive dissonance' about their practice and beliefs; to provide knowledge about the problem-solving model and to begin exploring relevant teaching strategies.

(ii) A three-week summer workshop that included four discipline sessions on physiology, geology, ecology and physics, carried out through means of lectures and laboratory and field experiences. There was role-playing led by the workshop staff simulating science students carrying out problem-solving activities until in-service teachers developed their own problem-solving activities.

(iii) Integrated problem-solving activities developed by the experimental group of teachers with their science classes.

(iv) Bi-monthly meetings held with the teachers to discuss the implementation of the model and to learn new strategies for questioning and co-operative learning from the instructional team.

The effect of the programme on changing the teachers' attitudes towards science teaching and on their use of problem-solving in teaching, was examined through means of an experimental pre- and post-test design. Twenty-two teachers participated voluntarily in each of the experimental and control groups. They were similar in gender, teaching status and educational background. Data on teacher attitudes (emotional, towards science, and role perception) was collected before the project and one year after its commencement. Teachers videotaped the lessons in which they were involved in problem solving, and an observation schedule was used to code these observations. All subjects, including the control group, completed an activity survey providing information about involvement in professional activities other than those of the workshop. The experimental group was also asked to keep an implementation log to record the problem-solving teaching strategies they used in the classroom. The data were analysed using a mixed factorial design with repeated measurements used for the two independent groups.

The main results indicated no significant differences regarding science teaching attitudes between the two groups. There were differences, however, in their teaching strategies. Contrary to expectations, experimental teachers worked in their classes with large groups rather than smaller ones for the problem-finding and the sharing/presenting phases of the strategy. But they used co-operative teams for problem refining, research designing, data collecting and analysing, and evaluating. (See *Table 8*).

The fact that the experimental teachers, compared to the control ones, spent more time on the problem-finding and refining and on the sharing/presenting aspect of the strategy indicates that they understood the importance of giving time to these steps and that they did transfer more responsibility on to students. Other differences in relation to the control group were a reduction in the percentage of time spent on lecture and procedural talk and more time on observing and listening to students. The researchers concluded that the experimental teachers appeared to be shifting to a more student-centred classroom.

Table 8. Long-term professional development schemes

Training objectives	Strategies	Outcomes
Science teaching knowledge		
• Increase content and pedagogical knowledge of middle-school science teachers. USA – Abell; Pizzini (1992)	Eight-month in-service activities: • Exposure to problem-solving model. • Stimulation of *cognitive dissonance* among teachers regarding practice and beliefs • 4 science discipline sessions with lectures, lab., and field experience (physiology, geology, ecology and physics). • Bi-monthly meetings.	Improved teaching strategies; • better quality of problem-solving; • less time lecturing and in procedural talk; • shift to a more student-centred classroom.
Collaborative research Academics and teachers: Constructivist perspective.		
• Understanding nature and mechanisms of teaching and learning in secondary science. Australia – White, Baird, Mitchell, Fensham; Gunstone, reviewed in Baker (1991	• Regular meetings of teachers and academics. • Sharing of ideas and findings from experience and development of teacher-initiated research projects.	Constant learning from experience. • Awareness of difficulties to be overcome such as conceptual misunderstanding and simplistic views of teaching and learning.
• Teachers' use of history as a means of eliciting conceptual understanding of school students. • Teachers' use of *cognitive dissonance* to elicit pupil construction of scientific concepts. Brazil – Carvalho, Pessoa de (1993)	• Training on how to use a 'historic' and 'dialogic' approach in teaching physics concepts such as 'heat and temperature'. • Video-taping of lessons to show relevant *teaching episodes* followed by analysis of these illustrating uses of history and activities that create cognitive dissonance.	• Successful teaching strategies emerged from analysis of videos. • A historical approach on its own is not effective, but with strategies such as cognitive dissonance is effective in producing conceptual understanding. • Awareness of difficulties in getting teachers to change approach due to the force of their established teaching practices. • Teacher awareness of their own shortcomings.

3.3 Collaborative research between academics and secondary teachers

Another form of in-service training is provided through collaborative research activities between academic staff and secondary level science teachers (see *Table 9*). Baker (1991) reviewed two of such reported activities. The first one, by Gurney, involved reflection on practice using teacher anecdotes, audio and video tapes of lessons, interviews with students, teacher-developed instructional materials and student products. The second study, by White, Baird, Mitchell, Fensham; Gunstone in Australia, is the *Project for Enhancing Effective Learning* (PEEL) which has been in operation in the State of Victoria, Australia for a number of years. This programme involves university academics who joined together with teachers to understand the nature and mechanisms of classroom teaching and learning in secondary science. Its activities include regular meetings, with sharing of ideas and findings from experience, and the development of teacher-initiated collaborative projects.

Table 9. Short-term in-service training schemes

Training objectives	Strategies	Outcomes
USA – studies reviewed by Koballa, Crawley; Shipley (1990):		
• Produce changes in needs, skills and attitudes of teachers and also on their students attitudes and self-concepts.	Summer Institutes.	Attitudes to science change in teachers and pupils, but no change in needs.
• Produce changes in teacher concerns.	Short-term intensive skills' oriented programme, focused on science demonstrations.	Change from low level concerns to higher level concerns about impact.
USA – reviewed in Baker, (1991:		
• Changes in secondary science teacher attitudes, concerns and knowledge about STS.	10-day summer workshop. Experimental evaluation of results.	Reduced concerns about teaching STS and increased knowledge about it. Pupils indicated higher positive attitude to STS.

University teachers at the University of Sao Paulo, Brazil (Carvalho, Pessoa de, 1993), operating from the perspective of Piagetian genetic epistemology and constructivism, undertook collaborative research with teachers as a form of in-service activity. Their project was aimed at influencing student understanding of scientific concepts through discussion of its historical origins, and at examining the construction of scientific concepts by students in the classroom, the role of teachers in constructivist teaching and the problem of school resistance to innovation.

The concrete focus of the investigation was the teaching of units on 'heat' and 'temperature' in secondary physics classrooms. In order to understand how teaching can aid in the construction of scientific concepts, teachers engaged in a number of activities aimed at creating cognitive dissonance among their pupils, while also involving themselves, together with the researchers, in a research literature quest for what is known about the kinds of 'heat and temperature' concepts young people develop. It was recognized that while it is not too difficult to develop activities that elicit students' existing concepts, it is more difficult to develop activities (questions, episodes, laboratory experiences, problems) which lead students towards the construction of scientific concepts.

As far as the effectiveness itself of the use of the history of science (or by that token, of any other discrete approach) to facilitate conceptual understanding, the researchers concluded that of itself it is not sufficient. But a historical approach linked to other approaches, such as conceptual dissonance and clarification, is effective in that it provides students with explanations for their doubts and questions and sets the stage for understanding the new concepts.

In terms of the effect of this collaborative teaching/research approach on teachers' professional growth, the researchers were struck by the difficulties that teachers find in changing their strategies ('didactic change'). It is one thing to discuss ideas about innovation in the teaching of physics in a reflective seminar context, and quite another to implement these coherently in the classroom. Teaching practices developed over time keep cropping up and need to be restructured similarly to the manner in which the restructuring of physics concepts occurs. In this respect, the kind of collaborative research activity just described was considered to have a formative effect on teachers in that it produced as much initial cognitive dissonance in themselves as it did in their students, thus setting the stage for further and more targeted professional development.

3.4 Induction programmes for novice science teachers

Sanford (1988) reviewed the North American, Western European and Australian literature on experiences and problems of novice science teachers, and concluded that little attention is given to the professional development of these teachers. Differences in the performance of novice teachers can often be attributed in the case of good performance to a well-balanced science background (in terms of the science disciplines) and to a teaching practice which was related to the present teaching assignment. On the other hand, teachers with limited background in the science they have to teach risk poor performance and need special assistance in the schools to which they are assigned. The literature contains growing evidence of the importance of mentor support in schools for novice teachers, preferably in the form of a well-structured programme of activities. But Sanford noted that having a good mentor programme is not the only condition for improved performance and support to novice teachers. Working conditions and factors such as curriculum requirements, textbooks and school/community goals are also important in facilitating or hindering performance. For all these reasons, she recommended, among other things, that attention to novice science teachers include matching their areas of expertise with their teaching assignments and not burdening them with excessive teaching and other requirements due to the large amount of preparation time they need. More importantly, however, attention should be given to team work through structured opportunities for interaction with other novice teachers, experienced teachers, supervisors, staff developers, or university-based instructors – not so much in a trainee capacity, but as contributors to group projects and the professional development of others.

4. Summary

In relation to pre-service teachers, research (summarized in *Table 7*) indicates that particular skills of a less complex nature, such as questioning or appropriate waiting time for pupil response, or of a more complex nature, such as using problem-solving skills in physics, are more effectively learned and practised if training in the use of these includes modelling with a strong trainer feed-back component and an equally strong reflective component on the part of the trainee. Also important, regarding training for laboratory teaching, is the provision of practical mechanisms to facilitate exploration of pupil understanding, to judge the appropriateness of the laboratory materials to be used and to test pupil competence in designing experiments and using process skills.

Improvement of the scientific knowledge background and especially of how to transform this knowledge into teachable material, indicates the possible effectiveness for such a purpose of techniques such as concept maps or conceptual diagrams embedded in group/seminar activities with ample space for feedback and reflective analysis; and also on instructional packages consisting of a number of activities aimed at improved understanding and better attitudes to science teaching. Other situations that centre on teacher reflectiveness-in or -on action proved effective in improving both teaching skills and learning more about subject-specific teaching.

The common thread running through *comprehensive training programmes* is not only their constructivist perspective but also their use of a number of different strategies (all well documented in the science teaching literature) to reach the goals of awareness, learning about teaching alternatives, trial and evaluative reflection, and successful implementation of teaching skills in the classroom. These strategies include: seminar structures, use of modelling of teaching strategies, video replays and discussion, mini-courses on science topics, pre-service lesson development (with in-built reflection) and action research projects. Evaluations of these programmes indicate changes among pre-service teachers, but also a dependency in the intensity and quality of these changes on contextual factors (workload, support in terms of resources and contact with teacher educators).

The studies on *short-term, in-service training schemes* point to the value of short experiences (during vacation time or other) for specific training in skills or a content area such as *Science Technology and Society* (STS), and for attitude change. These studies, which have involved experimental evaluations of their results, only tell, however, of the impact of the specific course or activity offered, shortly after the experience has taken place (generally, during the first year).

Nevertheless, they indicate that these activities are feasible and productive ways of bringing teachers together for very specific purposes and that with longer and institutionalized forms of professional development (within schools or school-focused) they represent a necessary component of the longer process of teacher development.

Several interesting findings can be highlighted from the reviewed studies on *long-term in-service training schemes*. An important one is that both attitude change and performance changes of a wider nature are observed. On the side of attitudes, the understanding that teachers acquire of the complexity of teaching and of their own conceptual and other limitations (both in relation to what teaching is and to pupils' needs) is a necessary factor in the building of relevant teaching strategies to overcome such limitations. This kind of personal growth is rarely achievable at the time of initial teacher training, or as a result of short courses later on; and therefore, long-term professional development activities are essential.

Chapter V
Secondary science teacher training experiences in selected countries

This chapter gives a description of teacher-training programmes which have attempted to introduce some innovation either in the style of training teachers or in the training structure itself, including its content. Maintaining the focus on Asia/Pacific and Latin America, we have selected instances from Papua New Guinea, Indonesia, Chile and Venezuela. The descriptions cover both pre- and in-service programmes.

1. Papua New Guinea

Pre-service secondary science teacher training is carried out at the University of Papua New Guinea in three different programmes: (a) a *diploma* in secondary teaching that prepares teachers for integrated science teaching in the lower secondary level of the system (provincial high schools); (b) a *bachelor* of education programme which also equips its trained teachers for lower secondary teaching; and (c) a *post-graduate* diploma in science that prepares for teaching at the upper secondary level (national high schools). The diploma programme, which until recently had a duration of two years, has been extended to three, and plans are underway to upgrade it to a four-year degree programme. It qualifies to teach in two subjects, and there is flexibility in the choice of subject combinations. The B.Ed. programme has a duration of four years and the post-graduate diploma is a one-year course offered to science graduates.

The science content of the B.Ed. and post-graduate programmes is similar in that all students follow a set of introductory courses in physics, chemistry, biology and geology (the Science Foundation year) offered in the Faculty of Science and then take a number of prescribed and elected courses in the main science subjects including some mathematics. Both groups join for the Education Year or the specific teacher-training programme taking place after completion of their science training. The B.Ed. students have one education course per semester, starting in the third semester of studies, but the Post-Graduate students have only the Education Year. The Diploma students, on the other hand, are trained in a concurrent programme (at the Goroka Teachers College campus), with about 50 per cent of time devoted to education and other general courses and the rest to the sciences through a curriculum especially designed for teacher training. They have an extensive programme of field-experience, culminating in a long teaching practice period in their final year.

There has been controversy over which of these programmes is better equipped to prepare secondary science teachers for the Papua New Guinea lower secondary curriculum, which has a focus on 'science for all' and is taught in integrated courses. Research by Guthrie (1983) based on interviews with supervisors indicated that diploma-trained science teachers were more competent in their teaching procedures than degree teachers, and that the converse was true regarding their subject knowledge. More recent case-study research by Haihue (1992), that based its findings on classroom observation of four differently trained teachers, found that overall (teaching procedures and subject knowledge) the more competent of these teachers was the degree-trained one and the least competent, a teacher trained in the diploma programme.

Regardless of which of the two types of programmes offers an overall more effective training, there is clear evidence that teachers trained in the shorter programme have less science preparation and find it difficult to teach the integrated science curriculum of the provincial high school. Because of this situation, the Ministry of Education has supported over the years the up-grading of diploma and certificate level teachers through the *Bachelor of Education (in-service)* at the University of Papua New Guinea. This programme, with a two-year duration, offers a combined set of education and subject-specialization courses in a wide variety of fields. Unfortunately, most of the science diploma trained teachers undertaking these studies in the last ten years were unsuccessful in getting their degree, to the point that teachers became discouraged about applying for entry.

At the heart of this situation was the level of difficulty and the nature of science courses offered in the Faculty of Science that could not be tuned to the entry characteristics nor interests of the science teachers concerned.

In view of the above situation, a decision was taken to develop an *ad hoc* science curriculum for the in-service science programme and that it be taught by persons with school teaching background, either in the faculty of education or the faculty of science. The programme is in operation *ad-experimentum* for five years, after which its results will be reviewed. The first group of five teachers successfully completed their studies early in 1993.

In the development of the programme there were several considerations, namely, that:

(i) the most urgent need of teachers would be upgrading in the knowledge and understanding of science;
(ii) participant teachers would be fearful of undertaking such studies and would need to be reassured by a supportive atmosphere and attention on the part of the staff in charge;
(iii) teachers, who had mostly been trained to use prescribed teaching strategies focused on behavioural objectives, would have to submit these practices to re-examination as they were confronted with alternative possibilities;
(iv) the science content would have to be so structured and organized that it would relate primarily to the broad aims of the school curriculum and student learning needs rather than to the concerns of the sciences as such.

On the basis of these principles, a set of science-for-teaching courses (mathematics, chemistry, biology, physics and geology) was developed by mixed teams of science education staff and subject specialists. Also included was a 'science curriculum and method course'. Even though the degree would be in education, a large portion of the programme was left to the science courses in the belief that teachers would need to involve themselves thoroughly in their subject, though always within the perspective of their role as teachers.

The programme has been subjected to a continuous formative evaluation (Avalos; George, 1993) and has had the assistance of a 'concerned outsider', a science education specialist an expatriate who has been able to gauge its progress and provide advice. In order to assess its results, the characteristics of science teaching in provincial high schools were initially examined (Haihue, 1992), records were kept by the programme lecturers of the participant teachers' characteristics and performance as well as a journal of their own experiences in the programme. All participant teachers were asked to teach a number of lessons at the end of their second year and to complete an evaluation of the programme as they perceived it. Structured and narrative observation of these teachers' lessons indicated important differences in relation to what is known generally about science teaching in Papua New Guinea (and, in particular, from Haihue's study to which reference has been made). Teachers attempted to conduct more inquiry-oriented types of lessons and use experiments where these were called for. Moving away from the general trend in science teaching in Papua New Guinea, to elicit recall/recognition interactions and repetition of concept definitions, these teachers were more concerned with interactions involving explanation, application and interpretation of knowledge. Some teachers made conscious efforts to explore students' initial understandings about concepts to be taught and they looked for as many examples as possible (verbal or material) to illustrate their explanations. In one case, when an experiment failed because of faulty dry cells, the teacher managed to find ways to solve the problem; in other cases of failure for logistic reasons, pupils themselves produced the solutions. The teachers managed to motivate their students' interest and arouse greater participation than is usual in other Papua New Guinea classrooms. It is of course not clear whether these teachers will persevere in their newly acquired practices and this will be assessed through periodic observations now that they are back in their schools.

In terms of their perception of the programme, the in-service teachers commented on several aspects. The content was considered 'moderately difficult' and some believed it could have been pitched at a higher level. The early expectations that they would acquire expertise to teach upper secondary (in fact, a promotion) were not fulfilled; but their hope in gaining confidence and skills to teach was in fact confirmed. They also felt that they had gained in terms of such activities as "learning about inquiry models in science curriculum" or "being able to prepare experiments in microbiology".

2. Indonesia

Launching a national *in-service programme* in Indonesia is no meagre achievement given the size of the population and its geographical distribution. However, the country has undertaken a number of programmes at primary and secondary level to improve the quality of teaching and pupil achievement. Realization of the inadequate implementation of the process approach in the teaching of science, after a number of research projects indicated this to be the case Nur (1993), has led to renewed attention to the many factors that may be at work here, including the quality of teachers. The *Pemantapan Kerja Guru* (PKG) programme is one of these aimed at the quality of science teaching in secondary schools.

In her recent study on *Secondary School Science in Developing Countries,* Ware (1992) documents the change processes experienced by this project and the current extension that is to take place with the assistance of a World Bank loan. The main features of this programme that originated as a set of workshops for science teachers in 1976-77 are noted below:

(i) Following the principles of the 'cascade' model of in-service training, it builds on training of instructors, who in turn provide in-service training to teachers and who in turn are expected to affect the quality of teaching in their schools and districts.

(ii) The training model assumes that teachers will improve their content knowledge and their teaching strategies and move from a teacher-centred to a more pupil-centred kind of pedagogy (UNESCO, 1988). It builds on the idea of time for training, awareness of needs, provision of alternative teaching models, improvement of content knowledge and continued feedback about improvement or difficulties in everyday practice.

(iii) The structure of the programme is as follows:

► *Training of instructors*: The first group of 12 teachers and subsequent ones were carefully selected as instructors. They needed to have at least five years of experience and a four-year undergraduate degree and to have been observed in order to determine the quality of their teaching. Their training consisted in a three-month study period involving content and teaching processes at UNESCO's *Regional Centre for Science and Mathematics* (RECSAM in Penang, Malaysia) and travel study in Thailand and Australia. Some of these teachers have had further studies overseas.

► *Training of teachers:* The PKG instructors conducted science teacher-training activities at regional and provincial levels in the following stages:

- *Two-week in-service activities* providing content knowledge, illustrating appropriate teaching strategies, training in laboratory skills and including teaching and peer observation with feedback.
- *Six weeks of on-service support* through visits from instructors offering feedback and advice on teaching difficulties.
- *Two weeks of further in-service training* followed by six weeks of on-service support.
- *Informal Saturday morning meetings* to cover curriculum aspects missed during the formal in-service training and to share their knowledge with other teachers.

While the model, because of its duration and feedback emphasis, certainly suggested a promising approach, it did not allow for wider coverage. As a result of this, from 1984 onwards a parallel system emerged whereby selected teachers trained in this system became in-service trainers (*Guru Inti*'s) of larger groups of teachers in much shorter training programmes (one-week non-residential training). Ware (1992) notes the problems associated with this approach given the limited duration of the programme and the lack of specialized training as instructors of the *Guru Inti*'s. She also indicates that there were conflicts resulting from lack of participation of initial teacher-training institutions and subject-matter teacher organizations.

A new World Bank-funded project has now been developed that will attempt to widen the scope of the programme to include greater decentralization from provincial to district level and transfer of responsibilities from the national instructors to the *Guru Inti* teachers, the establishment of subject-matter consultant boards to monitor and evaluate the programme, to involve provincial consultants from local teacher-training institutions, train the *Guru Inti* instructors through in – and on – service activities, to provide pedagogical and managerial training to all secondary school principals and to print, publish and distribute widely the instructional materials produced in the course of the project.

3. Chile and Venezuela

These countries illustrate the situation of other Latin American countries, where the secondary teaching force is generally trained through university studies and where policies towards widening access to secondary education have, in fact, resulted in many more students in the schools with different social background and intellectual experiences.

3.1 Venezuela

Pre-service teacher training in Venezuela is of the same level for all teachers but different according to the area of specialization (Organic Law, 1980). With the agreement of teacher-training institutions it was possible to determine a common training curriculum (de Barboza, de Tancredi; Pino, 1989). Thus, for example, secondary teachers in natural sciences and biology follow the same kind of courses, regardless of the institution in which they are being trained.

Support for *in-service training* and general improvement in the field of science teaching is co-ordinated by the *Centro Nacional para el Mejoramiento de la Enseñanza de las Ciencias Naturales* (CENAMEC) with assistance from universities and research centres, mathematics and science teachers and other national and international institutions. (See: Ware (1992).

In relation to needs of science teachers and, in particular, biology teachers, the CENAMEC carried out a survey in 1987 showing that 83 per cent of teachers had university qualifications and of those teaching biology, 79 per cent were qualified to do so; but only 50 per cent had experienced any form of in-service training. Their teaching styles were reported to be mostly of a lecture type and included laboratory, but few outdoor activities. Awareness of the situation had stimulated CENAMEC from very early on to organize in-service workshops aimed at the improvement of science teachers' practice. The effectiveness of the procedures and teaching materials used is assessed in terms of pupil achievement in the classrooms. ***Figure 4*** illustrates the processes and approaches used in these in-service workshops.

The environment. A resource for chemistry learning, was another topic developed in 27 workshops running from 1976 to 1984. During these workshops 685 teachers were able to design instructional units integrating environmental issues with chemical principles (Ware, 1992).

3.2 Chile

Reference has already been made in *Chapter II* to the characteristics of secondary teacher training in Chile. We would like to expand here on efforts aimed at restructuring the entire primary and secondary teacher-training curriculum in one training institution.

The Professional Institute of Osorno (a smaller university located in the South of Chile) is in the process of developing a curricular structure for secondary teacher training. It attempts not only to provide a concurrent model of training (content and pedagogy alongside each other), but to do so from a different theoretical perspective than that prevailing in other institutions. While most institutions training secondary teachers in Chile (Gysling; Salinas; Argandoña 1992) offer the pedagogical component as discrete courses in the area of Foundations and Methodologies with field-experience and practice teaching taking place towards the end of the programme, Osorno is experimenting with a system of seminar/workshop activities derived from the analysis of what is crucial to the preparation of teachers. In this respect, Pedagogy is recognized as a field of knowledge in its own right addressing the question of 'educational relationships' through examination of the epistemological foundations of educational practices, through providing a mediating role in the training

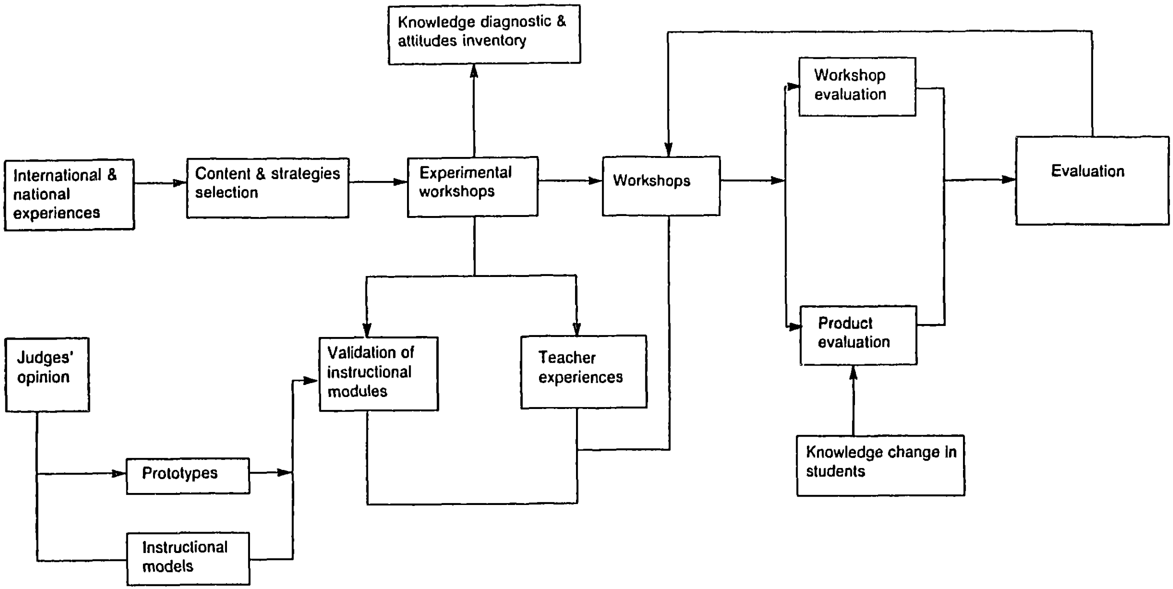


Figure 4: Structure of in-service training workshops in Venezuela

Source: de Bascones in Ware (1992).

In this respect, Pedagogy is recognized as a field of knowledge in its own right addressing the question of 'educational relationships' through examination of the epistemological foundations of educational practices, through providing a mediating role in the training process between theory and practice and through its investigation of ethical dimensions in the educational process (de Tezanos, 1993). The rationale for this approach is founded, among other things, on a critique of the 'technocratic rationality' and its strongly structured and prescribed formulas of 'know-how'.

As a result of this critique, the teacher-training programme has been radically altered, moving away from traditional courses in education foundations (psychology, sociology, philosophy), curriculum and methodologies towards a series of thematic seminars that run concurrently with the subject specialization. These seminars are grouped into general areas of educational theory, history of education, teaching theory, cognitive and affective development and pedagogical content knowledge. They involve not only 'learning about' and critical reflection, but also a practical component and evaluation of student learning through written reports and oral examinations. *Figure 5* shows the pedagogic components of the training programme.

The 'pedagogic practice' component of the programme that, as shown in *Figure 5*, runs parallel to the seminar work, includes: *fieldwork, observation, teaching*, and *classroom research.*

At present there exists a full implementation of this curriculum structure for mathematics teacher training while its application to the training of science teachers is under preparation.

4. Focus, contents and lessons from country cases

Table 10 shows what could be deemed to be the key aspects that countries are trying to incorporate as they introduce programmes of reform to their teacher-training procedures. In almost every case of reform, the concern is both with inadequate content knowledge of teachers and with teaching styles not conducive to increased pupil learning.

Table 10. Synthesis of country cases of innovation in science teacher training

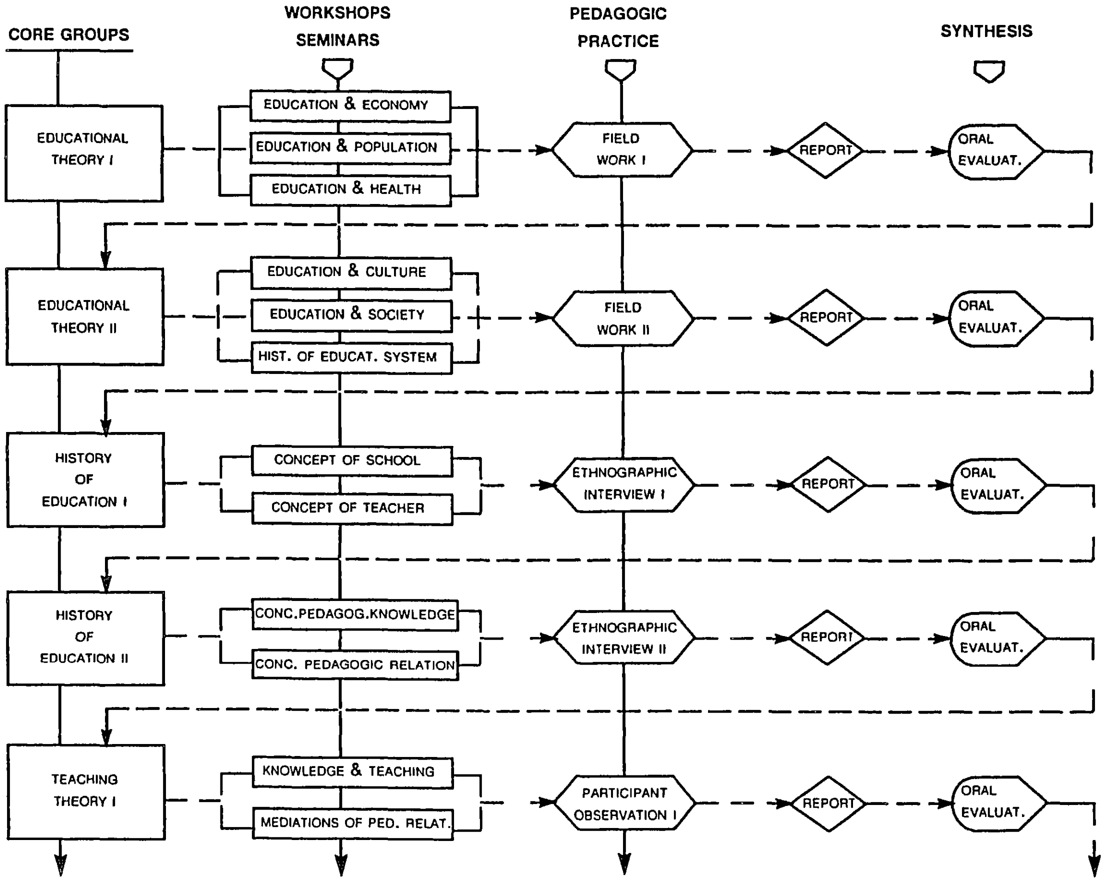
Country	Training level	Focus of experience	Results to date	Comments
Brazil (in Carvalho, Pessoa de, 1993; see *Chapter III*).	In-service	• Use of collaborative research with academics to experiment with constructivist approaches to teaching.	• Encouraging, but with awareness of difficulties in producing teacher attitude change, and more importantly change in their established styles of teaching.	• Though mostly a research project, it should be taken as an alternative model for organizing in-service activities that have a stronger chance to produce change in the long term. • To be successful, it requires available time and expertise.
Indonesia	In-service	• Cascade model geared to more pupil-centred pedagogy. • Involves training of instructors in content and process; and training of teachers at regional and provincial level.	• Initial structure of model did not allow for wide coverage; and has been modified through greater decentralisation of teaching functions. • Problems related to limited duration (16 weeks approx.) and lack of participation of teacher-training institutions.	

Table 10. (continued)

Country	Training level	Focus of experience	Results to date	Comments
Venezuela	In-service	• National Centre for Science improvement has been instrumental in carrying out programme of workshops on content and pedagogy, with emphasis on constructivism and science for all.	• Evaluations of specific workshops show good results. But there are no details as to long term effects.	• A novel approach is the concept of partnership between the Centre and universities and industrial corporations.
Chile				
1. Valparaíso (Cath. University)	Pre-service	• Specific strategies to improve practical skills of pre-service teachers, involving student-initiated activity, peer work, and classroom research.	• Enhanced student motivation and evidence of competent teaching skills. • Enhanced trainer motivation.	• Only successful in one subject where collaboration between teacher educator and science department is good (biology). Others, not interested.
2. Santiago (U. etropolitana)		• Curricular reorganizations (within consecutive model) to further closer integration between science content and pedagogy.	• No clear results yet, as programme has just begun. But it is expected that it will favour the capabilities to teach integrated science and science for all.	• Also difficulties of establishing appropriate communication between science departments and education depts. • Most innovative changes are occurring only in the teaching of physics.

Table 10. (continued)

Country	Training level	Focus of experience	Results to date	Comments
Chile				
3. Osorno (Prof. Institute)		• Thorough reorganization of consecutive training programme, to follow principles of constructivism, reflectiveness and integrated content-pedagogy training	• Implementation only for mathematics; science teacher training is projected. No evaluation yet.	• Interesting experience that would need following, to compare quality of graduates of this programme with those of others.
Papua New Guinea	In-service	2-year B.Ed. (Univ. PNG) programme was restructured and offered entirely within education faculty, but with strong focus on science contents.	• There had been no graduates among in-service teachers with science teaching specialization due to the nature of work in Faculty of Science. This programme has been successful in producing graduates, with changed attitudes to science teaching and better teaching skills.	• The overall structure and contents are adequate, but requires fine-tuning to allow for better fit between content and pedagogy. In part success depends on the motivation of students (high) and their initial state (science knowledge).


CORE GROUPS
WORKSHOPS SEMINARS
PEDAGOGIC PRACTICE
SYNTHESIS
EDUCATIONAL THEORY I
EDUCATION & ECONOMY
EDUCATION & POPULATION
EDUCATION & HEALTH
FIELD WORK I
REPORT
ORAL EVALUAT.
EDUCATIONAL THEORY II
EDUCATION & CULTURE
EDUCATION & SOCIETY
HIST. OF EDUCAT. SYSTEM
FIELD WORK II
REPORT
ORAL EVALUAT.
HISTORY OF EDUCATION I
CONCEPT OF SCHOOL
CONCEPT OF TEACHER
ETHNOGRAPHIC INTERVIEW I
REPORT
ORAL EVALUAT.
HISTORY OF EDUCATION II
CONC.PEDAGOG.KNOWLEDGE
CONC. PEDAGOGIC RELATION
ETHNOGRAPHIC INTERVIEW II
REPORT
ORAL EVALUAT.
TEACHING THEORY I
KNOWLEDGE & TEACHING
MEDIATIONS OF PED. RELAT.
PARTICIPANT OBSERVATION I
REPORT
ORAL EVALUAT.

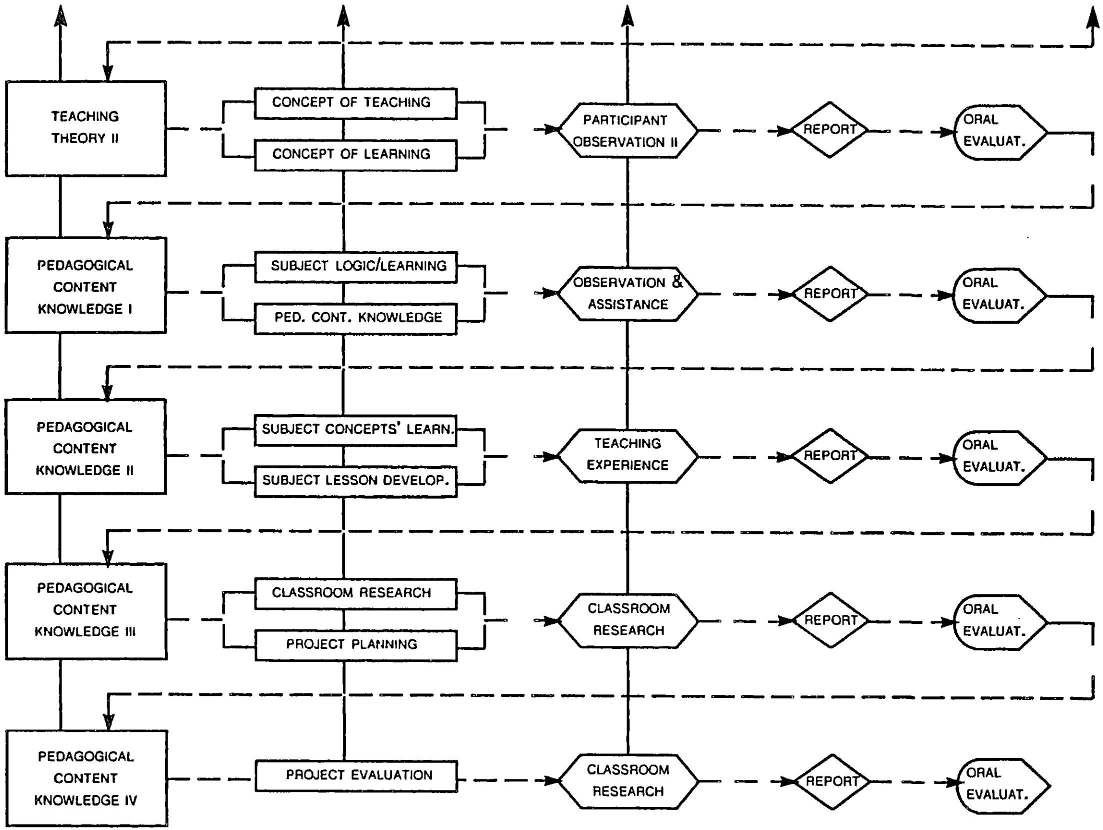


Figure 5. Teacher training curricular structure – Osorno Professional Institute

But also, although less pronounced than in the case of the research reviewed in *Chapter III and IV*, there is an underlying support for constructivism and pupil-centred teaching as being useful approaches (though not the only ones) in furthering the processes of science understanding and the aims of science and technology for all.

The cases, taken together, refer to almost all of the issues we have touched upon in this monograph: concern about structures (concurrent/consecutive); required changes in attitudes for science teaching and learning to become more meaningful; concern with learning about the 'particular' way of teaching the sciences (whether physics, biology, geology or chemistry) as well as about establishing conditions for integrated understanding of science; coverage (how to improve the quality of more teachers, with limited resources and geographical constraints to consider). The cases also reveal the difficulties of reform, thus illuminating the factors that affect success of programmes.

Chapter VI
Conclusion

In assessing the relevance that research reviewed in this monograph might have for the improvement of secondary science teacher training in developing countries, we need to remind ourselves of the contexts to which this research might apply. In general terms, when we speak of secondary science teachers we speak, on the one hand, of teachers whose science knowledge is the result of higher-level academic studies (such is the case in most countries in Latin America and Asia) which are prestigious in terms of the quality of such knowledge. On the other hand, we recognize that preparation for teaching is not necessarily adequate to help teachers bridge the gap between science learned within the conceptual framework of science itself and science that is of benefit to learners. Learners in the state school systems of Latin America and Asia vary enormously in their cultural and socio-economic backgrounds. Their pre-existing scientific explanations and their understanding of how to learn may be in conflict in many different ways with the learning experiences newly-trained teachers may wish to offer them. Equally, the resources necessary to teach science will differ from locality to locality, and from one type of school to another, so that the task of novice teachers if they are not made aware of how to cope with limitations, may be very difficult.

The research reviewed suggests that science teacher training, without necessarily leaving aside other approaches, may be improved through incorporating the principles of constructivism and reflective teaching. It also suggests an interesting *innovation/research agenda* to be carried out with a variety of instruments of data collection and analysis such as teaching observations, general interviews and discussions about instances, episode analysis, journals and other student-teacher produced material. It still recognizes the value for specific purposes of questionnaires and more structured forms of observation and interviews and of experimental designs, though most of the research reviewed relied on qualitative data. While implementing and evaluating an innovation on the spot is a starting point, it is also important to continue this research with follow-up of teachers in the field; and with investigation of the effects of the training approaches on pupil learning.

In the light of the experiences and research reviewed, it is possible to predict that the process of science teacher training will become more active in attempting to stimulate among student teachers the restructuring of knowledge and intellectual frameworks, in generating more affective dispositions as teaching becomes an interesting experience, and in facilitating a richer understanding of science and of its relevance. It is conceivable that this would also affect the quality of learning in secondary schools and by implication the number of people interested in science and technology. There is no reason to believe that these principles and experiences are not applicable to different socio-cultural and geographical contexts, provided the realities of these contexts are duly acknowledged as potentially favouring or lessening the adaptation.

1. Science for all

The concern with preparing teachers to tackle the purposes of 'science for all' is a very important one, but in most of the existing programmes of teacher training it is not directly addressed, perhaps because of the implicit assumption that it is really a curricular matter. Teachers will teach whatever curriculum is in place, and if such a curriculum has embedded contents and activities related to science for all, teachers should be able to tackle it. But, as expressed by many of the theorists, 'science for all' does not mean simply a set of contents and activities but an attitude to science that takes it away from its pedestal and sees its utility in the context of every-day life. This means more than teachers simply adapting to a curriculum, regardless of how good it may be. It means that teachers have to experience a continuous process of training which widens their perspective about the nature of science, its applications in daily life, and about how people learn science. Much of the research reviewed is geared towards this purpose of focusing on mastery of content that is teachable to real pupils, and not simply to the mastery of single sciences' content or of single teaching skills taken as separate entities. In all of this, there is a certain sense that more time is needed – time to train, to observe, to provide feedback, to have teachers reflect upon their experience and try out innovatory strategies. The feeling is that the need is not so much for expensive resources (although a minimum amount is necessary) because the role of laboratory science in its strictly experimental function may not be a requirement of 'science for all'. This does not mean that teacher training does not necessitate laboratory work as an aid to understanding science concepts and processes and being able to teach them. But beyond this, opportunity needs to be given to teachers, through training structures and training experiences, to reconceptualize the science they know and to focus on the students they will teach.

2. Science and technology, social and economic growth and teacher education

Although not overtly discussed, an implicit assumption of this study was the relation between the quality and relevance of science education and the efficient use of science and technology for social and economic improvement. While the school curricula of many countries may have changed to incorporate aspects of the broader conception of 'science for all', integrated science, or may have attempted to introduce technological elements, teacher-training procedures have not changed sufficiently to adjust to these new orientations.

It is obviously necessary, therefore, to review science teacher-training programmes, as the APEID/UNESCO Workshop (1991) indicates, and to do so on several fronts targeted at: the quantity and quality of contents; the character and quality of training procedures oriented to learner-centred and activity-based strategies; the links between teaching strategies and content knowledge through effective forms of practice, field induction and in-service up-grading; sufficient elements of technology education such as familiarization with tools, field-level experiences and the development of technological materials. For STS experiences to be effective, they need to be noted and incorporated as part of the learning alternatives embedded in science teacher training.

3. Content knowledge

Most secondary science teachers will have had university – (or tertiary) – level science formation. Theoretically, their understanding of science should be adequate. Yet, as gauged from discussions at various regional meetings on science education, inadequate conceptual understanding and connecting structures in this knowledge make it difficult to teach integrated science or bring specialized science to the level of a mass school population. There is obviously a conflict between the kind of science young people learn at science institutes and what is needed to make science education meaningful to all students and capable of attracting potential scientists.

From the literature we have reviewed we do not get clear guidance about such issues as what science should be learned at universities, with what depth and with what connecting emphases; although there are numerous suggestions about including content related to ecological and environmental issues and to technology. There seems to be a sense of frustration on the part of concerned science educators about inability to influence what is offered by way of science curriculum in university academic departments. This explains why so much effort is being put into science methods' activities in order to transform disjointed science information into 'pedagogical science knowledge' useful for teaching. Besides this, there are other avenues open to produce a thorough examination of the science curriculum required for prospective teachers. One of these relates to the management of science teacher training. In those instances where management is located within a science institute or faculty but the administrator's position is held by an educator, there is a possibility of dialogue among the parties and of influencing the structure and methodology of the courses offered. It is, of course, easier to provide a more relevant science content in pedagogical universities that have as their main function to train teachers (such as exist in many countries). However, there are drawbacks in such institutions insofar as training in pedagogical procedures may overtake in time and intensity the provision of quality science knowledge; while its science staff may not feel sufficiently stimulated to keep abreast of progress in their discipline.

This is why, in our opinion, it is wise to maintain the science knowledge component of teacher training within university science faculties or institutes (where such structures exist) and make provisions for regular processes of curricula and teaching procedures' review in line with science education requirements. These procedures should involve both the teacher educators and the science academics. In doing content revisions, it should be noted that the curriculum needed to train an 'integrated science' teacher is more difficult to structure and more difficult to teach than in the case of specialist teachers of physics, biology or chemistry. The curriculum requirements should allow enough time for the understanding of science concepts and the development of integrating cognitive structures. In this respect, it would not be advisable in a three or four-year undergraduate programme to require prospective teachers to add a second subject to their science specialization.[16]

In short, the need for a competent level of science knowledge among teachers will require, among other things, the review of science curricula offered by university departments, greater links between science and education staff in these institutions, introduction of new content areas and suppression of others, efforts to devise activities such as workshops and seminars that provide space for the integrating of science knowledge, and activities that lead to the recognition and restructuring of student prior conceptualizations about science.

4. Pedagogical training

To some extent it could be said that a teacher who is knowledgeable in his or her subject will have the confidence to teach imaginatively; in reality, however, and particularly in the case of science, there is more to teaching than knowing the subject. It is probably true to say that recent approaches such as constructivism open different perspectives to science teaching, particularly in their potential to affect understanding and

16. There are programmes that prepare teachers for lower secondary teaching in two subjects: science and a related subject such as mathematics or even a less related subject such as language or social sciences. The student has little chance to pursue any one of the subject areas in the depth required for teaching, and this is especially true for the area of science.

application of science concepts. However a shift to constructivism cannot be recommended as a simple panacea; it needs to be arrived at through processes that begin in initial teacher training and continue with in-service experiences. The research and cases reviewed in this monograph indicate several proposals to be considered in the implementation of a constructivist perspective: (a) contextualization of procedures through linking the learning of teaching approaches and teaching strategies to the teaching of science, as against pedagogical training based on general curriculum and methods courses followed by subject methodology teaching; (b) restructuring of student teachers' conceptual frameworks through reflective activities stimulated by theory (philosophy and history of science, cognitive theory, science education curriculum and methods approaches) and gradual introduction to the field of teaching and practice; (c) student modelling of teaching approaches (micro teaching, peer teaching) and enough supportive feedback from training staff; (d) student teacher production and trial of teaching materials; (e) action research through the reflective exploration of strategies and difficulties experienced during practice teaching. The routines of teaching such as producing lesson plans, managing lesson and classroom discipline and learning about assessment procedures, remain as training objectives; but with a different, non-prescriptive, emphasis. Instead, the emphasis needs to be one of adoption of teaching strategies after reflective experimenting with them.

Other issues discussed regarding the pedagogy of science teacher training refer to the opportunity or not of concurrent/consecutive models of teacher training. In many respects, concurrent models offer a better possibility to structure a coherent subject/pedagogy/practice type of programme according to the principles outlined above. However, this may not always be possible if existing university structures are rigid and difficult to change. In the cases where a consecutive programme would be difficult to alter, an *Education or Pedagogical Year* is crucial to the development of future science teachers and to the quality and coherence of their activities. Where this pedagogic training programme is as short as a year, it would be better to forego the much cherished but often disconnected general education courses (philosophy, sociology, curriculum theory) and focus on those activities better suited to the exploration and change of attitudes and transformation of 'declarative' knowledge into teachable knowledge.

Not all education systems contemplate a supported period of induction in the field before the certification of a teacher. When they do, generally there is no connection between the training institution and the novice teacher in the classroom. For logistic reasons it may be impossible to recommend that training institutions maintain support during the induction period; but it may be possible to meet with novice teachers during school breaks to reflect with them on their experiences and to provide advice. Many of the problems experienced by the novice teacher are of a 'coping' nature. Novice teachers have to cope with possible classroom management difficulties, they may encounter established teaching practices that run counter to those they developed through training and teaching resources may be limited. All these factors can discourage the recently trained science teacher even before she or he has been able to deal with the main objective of assisting pupils in the learning of science. The chance to discuss these in a supportive, non-threatening atmosphere could certainly help to ease the tension and assist in the finding of solutions.

5. In-service activities

As noted in the foregoing chapters, the continuing education of science teachers is important for a number of reasons. These are linked to the natural fact that teachers need opportunities to step back and look at problems associated with their practice, update their content knowledge and learn about new teaching resources or teaching approaches. Even more important is the fact that major changes of orientation have happened in the field of science education requiring a different type of readjustment to that considered important 20 or 30 years ago. These changes of orientation, which on the one hand stem from a better understanding of how learning of science takes place and, on the other, from a science curriculum more oriented to social and technological relevance, point to the need for in-service activities that are not mere information-giving types of activities.

We are reminded of a number of forms that have been suggested and reviewed in this monograph:

Science teacher workshops within schools or at district/regional level that, with external support, enable teachers to examine reflectively their teaching practice, develop alternative strategies, experiment with them and evaluate their results. The use of techniques such as modelling and peer teaching with feedback are regarded as particularly appropriate in this context. Thematic workshops for content knowledge improvement such as developed in Venezuela are useful as well.

Summer or vacation institutes held in centres with sufficient reference resources that are aimed at improving science content knowledge and/or the ways of teaching science. Research indicates that for greater effectiveness these institutes should have some sort of follow-up when teachers return to the field.

In situations where the content knowledge of teachers is limited (because of the nature of their initial training), *upgrading through in-service degree programmes* such as exist in Papua New Guinea, is recommended. It is important, however, that these programmes are organized in a way such that teachers do not find themselves sharing the same desk with their former school students in common undergraduate courses. Professional support and relevant content are essential components of a successful programme of this type.

The Master teacher system either through cascade procedures or directly within the context of short-term courses is proving of value in many contexts, as exemplified, for example, in the Indonesian experience of massive in-service training of science teachers.

Distance forms of in-service science teaching are useful provided carefully prepared materials are used and opportunities for face-to-face contact are at hand. Distance education can be counter-effective if the materials are poor and the suggested procedures and evaluation schemes (if these are in place) lead to memoristic learning.

There are many ideas for reforming science teacher training, some of which are being successfully implemented and others that await their trial in different contexts.

A final word in this respect would be to suggest that teacher-training institutions and, in particular, science teacher educators in developing countries, document their successful experiences and disseminate these where possible in journals of international circulation. This also means that training institutions should recognize that there is a whole field of research based on the implementation of novel training strategies that needs to be carried out collaboratively among teachers' educators, school teachers and student teachers. Learning through practice is a promising avenue for reform!

Bibliography

Abell, Sandra K.; Pizzini, Edward L. (1992). "The effect of a problem solving in-service program on the classroom behaviors and attitudes of middle school science teachers". *Journal of Research in Science Teaching* 29 (7), pp. 649-667.

Aguirre, José M.; Haggerty, Sharon M.; Linder, Cedric J. (1990). "Student-teachers' conceptions of science, teaching and learning: a case study in preservice science education". *International Journal of Science Education* 12 (4), pp. 381-390.

Akindehin, Folajimi (1988). "Effect of an instructional package on pre-service science teachers' understanding of the nature of science and acquisition of science-related attitudes". *Science Education* 72 (1): pp. 73-82

APEID/UNESCO (1984). *Training of science teachers and teacher educators. Report of a technical working group. Quezon City, Philippines*. Bangkok: UNESCO Regional Office for Education in Asia and the Pacific.

APEID/UNESCO (1989). *Science for all: strategies for curriculum development and teacher training*. Bangkok: UNESCO Principal Office for Asia and the Pacific.

APEID/UNESCO (1991). *Teacher training for science and technology education reform*. Bangkok: UNESCO Principal Region Office for Asia and the Pacific.

Avalos, B. (1992). "The need for educational reform and the role of teacher training: the case of Papua New Guinea". In *International Journal of Educational Development.* Vol.12. No.4. p.309-318.

Avalos, B.; George, T.S. (1993). *Evaluation of the B.Ed. (science) programme*. Progress Report.

Baird, John R.; Mitchell, Ian J. (1991). "Some theoretical perspectives on learning, teaching, and change". *Journal of Science and Mathematics Education in S. E. Asia* 19 (1), pp. 7-21.

Barba, Robertta H; Rubba, Peter A. (1992). "A comparison of pre-service and in-service earth and space science teachers' general mental abilities, content knowledge, and problem-solving skills". *Journal of Research in Science Teaching* 29 (10), pp. 1021-1035.

Barboza de, Diana R.; de Tancredi, Dalia D.; Pino, Lilian (1989). "Enseñanza de la Biología en Venezuela". In UNESCO/OREALC, *Enseñanza de las disciplinas científicas fundamentales.*

Borko, Hilda; Bellamy, Mary Louise; Sanders, Linda (1992). "A cognitive analysis of patterns in science instruction by expert and novice teachers". In Tom Russell and Hugh Munby (Eds), *Teachers and teaching. From classroom to reflection.* London: The Falmer Press.

Burbules, Nicholas C.; Linn, Marcia C. (1991). "Science education and philosophy of science: congruence or contradiction". *International Journal of Science Education* 13 (3), pp. 227-241.

Caillods, F.; Göttelmann-Duret, G. (1991). *Science provision in academic secondary schools: organization and condition.* Paris: UNESCO.

Carvalho, Anna María Pessoa de (1992). *Classroom research: an important factor in teacher training.* Paper presented at the VIIIth World Congress of Comparative Education: Education, Democracy and Development. Prague, Czechoslovakia, 8-14 July.

Carvalho, Anna María Pessoa de (1993). "Formaçao de professores sobre bases construtivista". In, Universidad de Sao Paulo, *A universidade e o aprendizaje escolar de ciências.*, Projecto USP/BID.

de Tezanos, Araceli (1993). *Formación de profesores para la enseñanza media.* Unpublished manuscript, Instituto Profesional de Osorno.

Driver, Rosalind (1988). "Restructuring the science curriculum. Some implications of studies on learning for curriculum development". In Layton, D. (Ed.). *Innovation in science and technology education,* Vol.II.

Driver, Rosalind (1988 a). "Theory into practice II: a constructivist approach to curriculum development". In Fensham, Peter (Ed.). *Development and dilemmas in science education.*

ECLA/UNESCO (1992). *Education and knowledge: basic pillars of changing production patterns with social equity.* Santiago, Chile: UNESCO.

Erickson, Frederick (1986). "Cultural differences in science education". In James J. Gallagher and George Dawson (Eds.) *Science Education and Cultural Environments in the Americas.* Interamerican Seminar on Science Education, Panama City, 1984. Washington, D.C.: National Science Teacher Association.

Fensham, Peter (1988). "Familiar but different: some dilemmas and new directions in science education". In Fensham, Peter (Ed.). *Development and dilemmas in science education.*

Fensham, Peter (1988) (Ed.). *Development and dilemmas in science education.* London: The Falmer Press.

Fensham, Peter J. (1992). "The curriculum of school science". *Directions Journal of Educational Studies, USP* 14 (1), 3-13.

Gallagher, James K. (1991). "Prospective and practising secondary school science teachers' knowledge and beliefs about the philosophy of science". *Science Education* 75 (1), pp. 121-133.

Garrett, R. M.; Satterly, D. (1990). "Turning exercises into problems: An experimental study with teachers in training". *International Journal of Science Education* 12 (1), pp. 1-12.

George, June (1989). "Sources of students' conception in science. The cultural context". *Journal of Science and Mathematics Education in S.E. Asia* XII (2), pp. 13-20.

Gess-Newsome, Julie; Lederman, Norman G. (1993). " Preservice biology teachers' knowledge structure as a function of professional teacher education: a year long assessment". *Science Education* 77 (1), pp. 25-45.

Gilbert, John (1989). "A contemporary model of science and mathematics education and teacher education". *Journal of Science and Mathematics Education in S.E. Asia* 12 (2), pp. 64-75.

Grossman, Pamela L.; Wilson, Suzanne M.; Shulman, Lee S. (1989). "Teachers of substance: subject matter knowledge for teaching". In Maynard D. Reynolds (Ed.) , *Knowledge base for the beginning teacher.* Oxford: Pergamon Press.

Gunstone, Richard (1988). "Learners in science education". In Fensham, Peter (Ed.). *Development and dilemmas in science education.*

Gunstone, Richard F.; Slattery, Monica; Baird, John R.; Northfield, Jeff R. (1993). "A case study exploration of development in preservice science teachers". *Science Education* 77 (1), pp. 47-73.

Guthrie, G.S. (1983). *An evaluation of secondary teacher education in Papua New Guinea.* Unpublished Ph.D. thesis, University of Newcastle, Australia.

Gysling, J.; Salinas, A.; Argandoña, C.L. (1992). *Modelos de formacion de profesores aplicados en las instituciones de educación media en Chile*. Santiago, Chile: Proyecto MECE/Media, Ministerio de Educación.

Hacker, R. G. (1988). "A model for the professional development of student teachers of science". *International Journal of Science Education* 10 (2), pp. 203-210.

Haihue, Samuel (1992) *Science teaching styles in Papua New Guinea high schools. A case study of four science teachers*. Unpublished B.Ed. (Honours) thesis, University of Papua New Guinea.

Hewson, Peter W.; Hewson, Mariana G. (1988). "An appropriate conception of teaching science: a view from studies of science learning". *Science Education* 75 (5): pp. 597-614.

John, Geryk (1991). "Teaching science by distance education". A perspective. *Papua New Guinea Journal of Education*, 27 (1): pp. 229-235.

Koballa, Thomas R.; Crawley, Frank E.; Shipley, Robert L.(1990). "A summary of research in science education – 1989". *Science Education* 74 (3), pp. 270-283.

Lanier, J.; Little, J. W. (1986). "Research on teacher education". In M.C. Wittrock (Ed.) *Handbook of research on teaching* (3rd ed.). New York: Macmillan.

Layton, David (Ed.) (1988). *Innovation in science and technology education*, V. II. Paris: UNESCO.

Lederman, Norman G.; Zeidler, Dana L. (1987). "Science teachers' conceptions of the nature of science: Do they really influence teaching behavior?" *Science Education* 71 (5), pp. 721-734.

Lindstrom, Lamont (1990). "Local knowledge in the South Pacific classroom". *Papua New Guinea Journal of Education* 26 (1), pp. 5 -17.

Mason, Cheryl (1992). "Concept mapping: A tool to develop reflective science instruction". *Science Education* 76 (1), pp. 51-63.

McDermott, Lillian (1993). *How we teach and how students learn*. Paper presented at the south Pacific regional Conference on Pre-Tertiary Physics Education. Waigani, University of Papua New Guinea.

Millar, Robin; Driver, Rosalind (1987). "Beyond processes". *Studies in Science Education* 14, pp. 33-62.

Millar, Robin (1987). Research notes. "Towards a role for experiment in the science teaching laboratory". *Studies in Science Education* 14, pp. 109-118.

Mohapatra, J.K. (1991). "The interaction of cultural rituals and the concepts of science in student learning: a case study on solar eclipse." *International Journal of Science Education* XIII (4), pp.431-437.

Muhlebach, Robyn (1992). "Science, technology and society education: perceptions, practice and issues". *Journal of Science and Mathematics Education in S.E. Asia* XV (1), pp. 81-94.

Nielslen, H. Dean; Tatto, María Teresa (1991). *The cost-effectiveness of distance education for teacher training.* Bridges Research Report Series, No 9.

Novak, Joseph D.; Gowin, D. Bob (1984). *Learning how to learn.* Cambridge: Cambridge University Press.

Nur, Mohamad (1993). *The development of the Indonesian high-school student's ability in using scientific method through physics teaching.* Paper presented at the South Pacific Regional Conference on Pre-Tertiary Physics Education. Waigani, University of Papua New Guinea, 22-25 June.

Olney, L.L.; Vlaardingerbroek, B. (1993). *Pre-tertiary students' misconceptions in mechanics.* Paper presented at the South Pacific Regional Conference on Pre-Tertiary Physics Education at the University of Papua New Guinea. Waigani, University of Papua New Guinea, 22-25 June.

Osborne, R. J.; Wittrock, M.C. (1983). "Learning science: a generative process". *Science Education* 67 (4), pp. 489-508.

Ost, David H.; Baird, William E. (1989). "Sources of experienced secondary teachers' skills and knowledge: A comparison of science teachers with other teachers". *Science Education* 73 (1), pp. 71-86.

Roberts, Douglas A. (1988). "What counts as science education?" In Fensham, Peter (Ed.). *Development and dilemmas in science education.*

Ross, Angus R. (1993). *Science achievement in Papua New Guinea. Matching curriculum development with assessment strategies.* Unpublished D. Phil thesis, University of Sussex.

Sabrovsky, Eduardo (1992). "Experiencias en educación tecnocientífica en el hemisferio norte: el caso de la educación en ciencia, tecnología y sociedad (CTS)". Paper presented at the meeting on *Experiencias Educativas Relacionadas con el Desarrollo Científico y Tecnológico, Enseñanza de la Tecnología y Formación para el Trabajo*, Santiago, Chile: CIDE.

Sanford, Julie P. (1988). "Learning on the job: Conditions for professional development of beginning science teachers". *Science Education* 72 (5), pp. 615-624.

Schön, Donald A. (1987). *Educating the reflective practitioner: towards a new design for teaching and learning in the professions.* San Francisco: Jossey-Bass.

Schön, Donald A. (Ed.) (1991). *The reflective turn. Case studies in and on educational practice.* New York: Teachers College Press.

Schwab, Joseph (1962). "The teaching of science as enquiry". In Schwab, Joseph and Brandwein (Eds.), *The teaching of science.* Cambridge, MA: Harvard University Press.

Shulman, Lee (1987). "Knowledge and teaching: foundations of the new reform". *Harvard Educational Review* 57 (1), pp. 1-22.

Summers, M.K. (1982). Philosophy of science in the science teacher education curriculum. *European Journal of Science Education* 4 (1), pp. 19-27.

Swartland, Jakes (1988). "Interdisciplinarity in the teaching of science during the first nine to ten years of basic education". In Layton (Ed.), *Innovation in science and technology education,* V.II.

Tamir, Pinchas (1989). "Training teachers to teach effectively in the laboratory". *Science Education* 73 (1), pp. 59-69.

Thomaz, Marilia F.; Gilbert, John K. (1989). "A model for constructivist initial physics teacher education". *International Journal of Science Education* 11 (1), pp. 35-47.

UNESCO (1988). *A fresh look at teaching physics at school level. Report of the UNESCO Regional Workshop on the Training of Physics Teachers, 18-20 November 1986.* Bangkok: UNESCO Principal Regional Office for Asia and the Pacific.

UNESCO/OREALC (1989). *Enseñanza de las disciplinas científicas fundamentales (Física, Química, Biología).* Santiago, Chile: UNESCO.

Vlaardingerbroek, Barend (1990). "Ethnoscience and science teacher training in Papua New Guinea". *Journal of Education for Teaching* 16 (3), pp. 217-223.

Waldrip, Bruce G.; Giddings, Geoffrey J. *(1993). Educational Productivity and Science Education within Papua New Guinea High Schools.* Paper presented at the South Pacific Regional Conference on Pre-Tertiary Physics Education. Waigani, University of Papua New Guinea, 22-25 June.

Ware, Sylvia A. (1992). *Secondary school science in developing countries. Status and issues. PHREE* Background Paper Series. Washington: The World Bank.

Yeany, Russell H.; Padilla, Michael J. (1986). "Training science teachers to utilize better teaching strategies: a research synthesis". *Journal of Research in Science Teaching* 23 (2), pp. 85-95.

IIEP publications and documents

More than 750 titles on all aspects of educational planning have been, published by the International Institute for Educational Planning. A comprehensive catalogue, giving details of their availability, includes research reports, case studies, seminar documents, training materials, occasional papers and reference books in the following subject categories:

Economics of education, costs and financing.

Manpower and employment.

Demographic studies.

The location of schools (school map) and sub-national planning.

Administration and management.

Curriculum development and evaluation.

Educational technology.

Primary, secondary and higher education.

Vocational and technical education.

Non-formal, out-of-school, adult and rural education.

Copies of the catalogue may be obtained from the IIEP Publications Unit on request.

The International Institute for Educational Planning

The International Institute for Educational Planning (IIEP) is an international centre for advanced training and research in the field of educational planning. It was established by UNESCO in 1963 and is financed by UNESCO and by voluntary contributions from Member States. In recent years the following Member States have provided voluntary contributions to the Institute: Belgium, Canada, Denmark, Finland, Iceland, India, Ireland, Norway, Sweden, Switzerland and Venezuela.

The Institute's aim is to contribute to the development of education throughout the world, by expanding both knowledge and the supply of competent professionals in the field of educational planning. In this endeavour the Institute co-operates with interested training and research organizations in Member States. The Governing Board of the IIEP, which approves the Institute's programme and budget, consists of a maximum of eight elected members and four members designated by the United Nations Organization and certain of its specialized agencies and institutes.

Chairman:
Lennart Wohlgemuth (Sweden), Director, Nordic Institute of African Studies, Uppsala.

Designated Members:
K. Y. Amoako, Director, Education and Social Policy Department, The World Bank.
Harka Gurung, Director, Asian and Pacific Development Centre (APDC), Kuala Lumpur.
Cristián Ossa, Director, Macroeconomic and Social Policy, Analysis Division, Department of Economic and Social Information and Policy Analysis, United Nations.
Tito Egargo Contado, Chief, Agricultural Education and Extension Group, Human Resources, Institutions and Agrarian Reform Division, Food and Agriculture Organization (FAO).

Elected Members:
Isao Amagi (Japan), Special Adviser to the Minister of Education, Science and Culture, Tokyo.
Mohamed Dowidar (Egypt), Professor and President of the Department of Economics, Faculty of Law, University of Alexandria, Alexandria.
Kabiru Kinyanjui (Kenya), Senior Programme Officer, Social Sciences Division, International Development Research Centre (IDRC), Nairobi.
Tamas Kozma (Hungary), Director-General, Hungarian Institute for Educational Research, Budapest.
Yolanda M. Rojas (Costa Rica), Academic Vice-Rector, University of Costa Rica, San José.
Michel Vernières (France), Professor of Economic Sciences, University of Paris I, Panthéon-Sorbonne, Paris.

Inquiries about the Institute should be addressed to:
The Office of the Director, International Institute for Educational Planning,
7-9 rue Eugène-Delacroix, 75116 Paris, France.

The book

New or changed approaches to science education – such as integrated science, discovery learning, science for all, etc. – pose a series of crucial questions relating to teacher training: to what extent and in what ways are these new orientations considered and implemented within the context of science teacher education? How are teachers being prepared, through training, to stimulate more young people to interest themselves in science and the use of science and technology? What kind of training structures could assist the development of both a sound content foundation and an improved capacity to teach science subjects?

It is the purpose of this monograph to provide information and research results on the current situation of science teacher training and stimulate discussions about the most relevant related issues. Furthermore, this volume looks at crucial changes that are actually being experimented upon in different countries of the world – to improve the training of secondary science teachers in the light of the recent orientations of science education.

The author

Beatrice Avalos has a longstanding and widely acknowledged experience in the field of teacher training and, more generally, in research on qualitative aspects of education in Latin America and other parts of the world. She has worked as a lecturer and researcher at different universities (in her home country Chile, the United Kingdom, Papua New Guinea) and as a consultant for various international agencies. Among her numerous previous publications are *A review of teacher effectiveness research in Africa, India, Latin America, Middle East, Malaysia, Philippines and Thailand: synthesis of results*, 1981, (with Haddad, Wadi); *Teaching the children of the poor: an ethographic study in Latin America*, 1986; and *Approaches to teacher education: initial teacher training*, 1991.