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Scientific and Technological training for Tradtîtional Communities. Raül Gagliardi.

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SCIENTIFIC AND TECHNOLOGICAL TRAINING FOR TRADITIONAL COMMUNITIES

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The International Bureau of Education is launching a research project on the training of teachers for intercultural education. The project is called 'Basic Education for Participation and Democracy: Key Issues in Human Resources Development (Teachers and Multicultural/Intercultural Education)'. The general objective of the project is to develop countries' capacities to improve basic education, especially in multicultural contexts, and particularly through teacher training. Another objective of the project is to improve teachers' capacities to educate minorities, which is an important element in the building of a more democratic society.

This article summarizes the results of the project and integrates them with strategies and methods developed by the Laboratoire de didactique et épistémologie des sciences of the University of Geneva, the Department of Biology of the University of Pavia and other research and training centres in Europe and Latin America.

Introduction

Many traditional communities are experiencing a rapid process of transformation. They are changing their way of life, their members are migrating to urban areas and undertaking new activities. When members of traditional communities leave behind their society and adopt a modern style of life, valuable knowledge is lost, and they often adapt poorly to the new living conditions. Alcohol and drugs are

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frequently the answer to the discrimination and low self-esteem they suffer. A common result is that pupils from traditional communities are less successful than pupils from other communities.

Many traditional communities want to maintain their way of life. However, their contact with Western civilization is growing and the pressure for change is increasing.

The teaching of science and technology could improve the situation of members of traditional communities by enhancing their use of resources while reinforcing their self-esteem and improving their performance in schools. Science and technology teaching could allow the maintenance of traditional knowledge and integrate it with modern knowledge.

The gap between traditional beliefs and scientific knowledge is not easy to bridge. This is not a philosophical question, but rather a very practical one; learning basic scientific concepts is very difficult if the learning obstacles presented by language and culture also have to be overcome.

Experience shows that results are better when science and technology teaching is consistent with traditional teaching methods, adapted to the characteristics of the community and low in expenditure of time and money. One Maori educator and political leader summarized the problem of science teaching for traditional communities by saying: 'give us the science, but maintain our pedagogy' (Ohia, 1990). In other words: maintain the traditional ways of transmitting information to new generations while providing useful scientific and technical knowledge.

The adaptation of teaching to the learners' culture is a very important element in science and technology instruction in any society, in any school. In traditional communities, adapting the teaching of basic scientific concepts to the community, its traditional knowledge and its beliefs is a fundamental element for success.

Knowledge about the characteristics of the community is therefore as important for the teacher as scientific and technical knowledge. The teacher should be capable of constantly evaluating his/her activities and adapting them to the community's degree of understanding and motivation about any proposed technological changes. He/she should anticipate resistance to technological changes in the community and interact smoothly when necessary. These ideas are consistent with a basic hypothesis developed in the teaching of science: a successful approach to improving science teaching results from an analysis of learners' concepts, attitudes and needs, and applying this information in teaching.

This methodology developed in the teaching of science could be integrated with the results obtained from research on multicultural education to provide a framework for improving science and technology teaching in traditional communities.

Improving the quality of life

The failure of development programmes in many developing countries and the problems caused by poverty, underdevelopment and environmental degradation are strong justifications for organizing educational programmes specifically addressed to traditional communities. Another element to be borne in mind is the discrimination suffered by traditional communities and the illiteracy—and scientific illiteracy—of most of their members.

Members of traditional communities can use basic scientific knowledge to improve the quality of their lives. For example, basic knowledge about micro-organisms is useful for improving public health. A health education campaign organized around such knowledge can reduce the high mortality and morbidity rates found in developing countries. Improving the quality of handicrafts can augment their market value. Improvements in conservation techniques can lead to a rise in the quality of food products and prevent them from deteriorating, thus reducing illness and mortality caused by diseases arising from poor conservation. Since many women walk five or ten kilometers to obtain wood for cooking, knowledge about solar cookers can lead to significant savings of time. The use of solar cookers can also reduce the incidence of eye diseases provoked by smoke produced from burning cow dung or wood for cooking—a significant problem suffered by women in developing countries.

Major environmental problems caused by human activities can also be reduced by introducing basic scientific knowledge into traditional communities. For example, basic knowledge about energy can be used to reduce deforestation resulting from the burning of wood as fuel for cooking. Knowledge about the dynamics of fish populations can be useful in reducing the negative impact of overfishing which may bring about the disappearance of certain species.

An analysis of costs/benefits and a measure of the impact of innovations at the ecological, economic, cultural and social levels may reduce problems associated with introducing innovations necessary for improving the quality of life. Therefore, science and technology instruction should not be limited to a simple transmission of information; it should develop the capacity to understand the reasons for these techniques and to analyze the costs and the impact of their implementation.

The transmission of basic scientific knowledge for sustainable development can be undertaken through different channels. Basic education is one of them, if appropriate educational activities are carried out and teachers develop the new capacities necessary as agents for sustainable development. This approach requires teachers who can interact with the learners' culture while teaching.

Pupils may transmit to their families the basic scientific concepts they have learned in school, if these concepts are appropriate for solving day-to-day problems. If this approach is used, pupils may become agents for sustainable development in their families and in their communities.

Pupils from traditional communities frequently have to participate in work with their families. This situation leads to difficulties in their studies and reduces the duration of their schooling. For example, children from nomadic communities leave school during migrations, and pupils from agricultural communities leave school during the harvest season.

Science and technology instruction should consider these activities. Learners' experiences in productive activities can be exploited in science instruction. Analysis of traditional activities can support science and technology instruction while the basic scientific concepts learned in the school can, in turn, contribute to improving traditional productive activities.

In a traditional community where fishing is an important activity, an analysis of fish conservation methods can be the basis for teaching about micro-organisms. Starting from such an analysis, it is possible to focus the lesson on the action of micro-organisms that cause fish to decay, showing that freezing, salting, drying or smoking are methods for preventing the multiplication of micro-organisms, and that hygiene is a way to reduce the quantity of micro-organisms and insects present. This analysis of methods to prevent action by insects can be used to overcome beliefs about the spontaneous generation of life and can be integrated into teaching about ecosystems and insect life-patterns.

In communities where agriculture is the main activity, analysis of farming methods can be the basis for teaching about such subjects as the transfer of matter and energy in environmental systems, or photosynthesis and plant nutrition. In return, an understanding of related scientific concepts can be the basis for improved farming methods.

Discussion about traditional methods should not be reduced to a few lessons about traditional culture. Analyses of traditional activities should be integrated into the mainstream educational activities, particularly in courses about science and technology. These analyses require information about traditional methods, and scientific knowledge about the processes involved. Therefore, research about traditional knowledge and its integration into science and technology teaching should be organized to obtain this information.

Building scientific concepts

An important element in training traditional communities is that the information should not be merely a ready-made solution, but rather an organized series of basic scientific concepts.

One temptation is to reduce training to a series of skills that can be mastered without any scientific explanation. Some advantages of this method are the rapidity of the instruction and the apparent elimination of cognitive problems. The basic idea is that it is easier to learn a series of tasks than to build new scientific knowledge that may contradict traditional beliefs. This skill-centred model seems to be readily adaptable for teaching in traditional communities. Therefore, the training of instructors in multicultural contexts is frequently oriented more to communication methods (how to teach the skills) than to the scientific content. However, experience shows that this approach has serious limitations. For example, it does not develop the community's capacity to grasp the reasons for the proposed techniques and adapting them to changing conditions. Another disadvantage is that it does not provoke the necessary conceptual changes in community members; some of them may acquire the proposed skills, but the community does not build a new conceptual framework as a support for understanding and solving the main problems. The most important objection to this approach is that it does not develop the community's capacity to understand the real problems, their causes, the possible solutions, which solution is best, and what are the possible repercussions of the chosen solution.

I propose a different approach: to focus teaching on basic scientific knowledge that can develop an understanding of the causes of problems and ways of solving them. New skills should be understood as a logical response to the causes of the problems, and not as a simple list of tasks to be performed without explanation. The accent might be put on understanding the causes of the community's problems, and giving a scientific explanation of the community's empirical knowledge. The necessary modifications for the community's activities will be deduced after learning the basic scientific concepts explaining the cause of the problem and a possible solution.

Let me give an example. Infant mortality is a major problem in developing countries; in particular, the tetanus bacillus is a leading cause of death among newborn babies. Contamination of the instrument used by midwives to cut the umbilical cord is one common way of transmitting this micro-organism.

A course to train traditional midwives was organized in Peru. One of its goals was to teach ways of sterilizing the instrument used to cut the umbilical cord. However, a few months after the course, no change in infantile mortality was observed: more particularly, there were no changes in the rate of tetanus infection in newborn babies. Observation of the activities of traditional midwives who had been trained in the course showed that the steps for sterilizing the knife were perfect, but after sterilization and before cutting the cord, the knife was often placed on the floor. The midwives had learned the techniques of sterilization, but they did not understand the concept of contamination. They had learned how to sterilize, but they did not learn why it is necessary to sterilize. To avoid contamination, it is not only necessary to know the rules of sterilization, but also to know about the existence of micro-organisms and their multiplication. Without this knowledge, sterilization becomes only a series of gestures.

This example shows the importance of teaching basic knowledge about micro-organisms. These concepts are also important for other health problems. In some countries, 80 per cent of illness results from water-borne diseases. In developing countries, 25 per cent of mortality is caused by poor food conservation. An important obstacle in the understanding of the existence of micro-organisms is that they cannot be seen with the naked eye (even if their effects are perceptible). The notion of their presence everywhere runs against the physical evidence.

Observation of different phenomena provoked by micro-organisms is not sufficient for understanding their existence, but it is always possible to give another explanation, especially a magical one. For example, a child's death by tetanus can be interpreted as the result of occult forces, or in a fatalistic way. Phenomena, like the contamination of food by micro-organisms, are frequently explained as 'spontaneous transformation of matter' or 'reaction of the food with the air'.

The concept of micro-organisms provides an explanation for infectious diseases, environmental processes such as the transformation of organic matter into inorganic matter, and some technologies such as the production of alcohol or food conservation. This concept is the basis for scientific knowledge as well as very practical activities.

Using traditional knowledge

Curricula for basic education are frequently monocultural. They dwell on the history and beliefs of the dominant group. This situation may reinforce feelings of discrimination among pupils from minorities, and may cause pupils to lose their cultural identity and self-esteem. It is also a cause of poor scholastic achievement among pupils from the minorities discriminated against. This is a major disadvantage both in obtaining good jobs and for integration into society. Appropriate curricula for multicultural/intercultural education should integrate some of the history and characteristics of all communities.

Traditional communities have very accurate knowledge about their territory and have developed specific technologies for dealing with basic needs and the exploitation of their territory's resources. Traditional knowledge and technologies are not scientific; they were not developed using scientific methods and they are not supported by scientific theories.

Traditional knowledge and technologies are transmitted to new generations by tales, stories, proverbs, etc., which frequently include magic as an explanatory factor. Analysis of these elements could allow their use in science and technology instruction.

Traditional communities frequently have low self-esteem. This attitude results from centuries of domination and is related to their standard of living. The low standard of living (compared with the dominant social group) reduces self-esteem. Low self-esteem is an element which impedes activities which may lead to an improvement in the standard of living. Thus the learners' self-esteem is an important element for success or failure during teaching. The learner who has low self-esteem is not motivated to learn and has more difficulty convincing himself/herself that he/she is capable of learning.

The global question is: How can a traditional community be trained to improve its quality of life while at the same time maintaining its identity and improving its self-esteem?

Let me relate a story from Togo. A French counterpart (who told me the story) was responsible for training future teachers. She prepared practical lessons in biology, in particular on fermentation. Being sensitive to learners' difficulties and wanting to use traditional culture in teaching, she considered how she might employ traditional knowledge in science teaching. As in many African communities, it was the women of the region who prepared beer using traditional methods. She asked the students to gather information about the traditional techniques for preparing beer.

The students asked their mothers and brought the information back to the course. During the following discussions, they were at first reluctant to talk about the way their mothers produced beer; they were ashamed of the magic rituals involved. However, after a brief discussion, they accepted to present the information obtained. The analysis produced a very important result: in the different communities the magic rituals were different, but the practical activities were the same and, what is more important, they bore similarities to the modern beer production methods. The conclusion was obvious: each tribe, each mother had practical knowledge about fermentation transmitted through magical beliefs.

The question was: How to use these beliefs and empirical knowledge in science teaching? For example, the mothers said: 'it is necessary to use an old container to produce beer, because the god of the beer (or the spirit of the beer) lives in it'. The spirit of the beer living in the old container is, in scientific jargon, the micro-organisms that will lead to the fermentation of sugars into alcohol.

Empirical knowledge showed the necessity of using an old container to produce beer and the consequent explanation of the phenomena was related with the sacred or spiritual world. The absence of scientific explanations encouraged the concept of 'the god of the beer' as a cause of an important phenomenon. It is probable that the community reinforced its beliefs in a sacred or spiritual world by also applying them to current observable phenomena. The building up of religious or magical beliefs was an important element in the building of social and cultural rules.

The students were ashamed to talk about the magical rituals carried out by their mothers because these traditional activities did not correspond to the Western scientific world they admired. A process of acculturation and loss of identity was in motion. However, the understanding of the relationship between, and utility of, traditional techniques and knowledge changed this situation. The students were proud of their tribes who had produced empirical knowledge that was scientifically correct. Not only can traditional knowledge be the starting point for teaching scientific concepts, but its use can improve community self-esteem.

The mystic beliefs of the community can obstruct teaching if the teacher is not aware of them. However, these beliefs are frequently linked with empirical knowledge and can be a vehicle for empirically correct information. This duality is a fundamental characteristic of the traditional community, which learns from experience and transmits the knowledge by integrating it into a system of mainly mystical beliefs. Therefore, the teacher should not fight against the mystic beliefs, but regard them as obstacles to be overcome and as elements that can be exploited in teaching.

Science and technology instruction for traditional communities can be organized around traditional tales and stories related with traditional knowledge. A good example is the 'Gayngaru Plant Walk', a booklet for a course about botany in Nhulunbuy Primary School (Northern Territories, Australia). The text, addressed to primary school-teachers, tells the traditional story of the 'Wititj' (olive python) and gives information for organizing a journey in the bush country near the school. The text gives information about the walk and about the thirty-four plants which can be observed during it, describing their traditional use and their scientific names. For example:

Corky bark (Dhuyuwur): the pale green, fleshy fruits can be eaten when ripe or crushed to treat inflammations, sores or sore eyes. The botanical name of the plant is *Opilia amentacea.*

Using scientific concepts

Developing the community's capacity to solve basic problems and motivating it to undertake long and difficult activities involves more than simply providing it with ready-made answers. It requires the teaching of basic scientific concepts.

Basic scientific knowledge builds a new understanding and empowers the community to improve its quality of life. This basic scientific knowledge should be pertinent for the situation and for the community. Its relevance for the environmental, social and economic situation is evident. The lack of resources and poverty in traditional communities suggests the necessity of focusing education on themes related to swiftly improving the quality of life and the solving of urgent problems. Basic scientific knowledge should be adapted to the main problems that the community must solve to improve its quality of life.

However, adapting to the main issues is just one factor in deciding what scientific concepts should be taught to a traditional community. Basic scientific knowledge should be accepted by the community, because if the community does not understand the need for it, it will not do what is necessary to transmit and exploit it. In practical terms, if the members of the community responsible for validating and transmitting knowledge do not think it is important in solving specific problems, they will not transmit the knowledge to other members. Leaders, grandmothers or teachers—all who participate in the diffusion of knowledge—should be aware of the importance of the basic concepts to be transmitted to the community.

The success or the failure of an educational campaign depends on this acceptance. Would a community organize new activities if it was not convinced of their importance? The proposed innovations should be adapted to real conditions in the community. They should be acceptable in economic, cultural, technical, social and religious terms. They should also be consistent with the characteristics of the production and marketing system and consumer habits.

A good example of the mobilization of a community for new activities based around a new concept is given by two indigenous Andean communities in Ecuador. They carried out arduous work on a grand scale—digging fifty kilometers of canalization at high altitudes—to obtain pure water. Activities such as piercing tunnels through the mountains were organized after the community leaders understood a basic concept that they expressed as: 'the bad water kills our children'. Community leaders convinced the other members of the community and motivated them to become involved in very hard and unpaid work, but only after they had understood the relationship between contaminated water—'bad water'—and child mortality. The concept of a relationship between water and child mortality was pertinent for the community, and the community members developed new activities after they had grasped the concept.

Using understandable language

The preceding example demonstrates another important point in transmitting basic scientific knowledge to traditional communities. A scientific concept is not understood if it is not expressed in the language and words of the community. For a scientist, 'bad water' is not scientific, yet for the educator it can be the basic expression inspiring the complete system of training in order to obtain drinkable water.

Learning about 'bad water' is a step in becoming aware of water-borne diseases and pathogenic micro-organisms, basic concepts for the community's health improvement. Important elements in transmitting basic scientific concepts to a traditional community are to put them into colloquial language, use local examples and, when possible, exploit traditional tales or stories. Learning a scientific concept should not be made more difficult by employing words that are unknown to the community. More important than the words are the concepts they carry: scientific concepts should be understood in colloquial language. The concept should be built by the learner before he/she knows the corresponding scientific word. Scientific and technology teaching should be focused on the learning of basic scientific concepts and not on memorizing scientific words.

If we accept that the learner builds his/her own knowledge, we can easily accept that he/she uses the language and concepts he/she already knows. Therefore, it is necessary to use an understandable language in the presentation of basic scientific concepts. However, to use comprehensible language does not mean to reduce the scientific value of the information. This is a key point in education: how to transmit correct scientific information using understandable language?

Translating science into traditional languages

It often happens that science and technology texts do not exist in traditional languages. Translating them into traditional languages can be an important step in developing the scientific and technological capacities of traditional communities. The difficulties in translation are considerable, particularly when the language does not have a basic scientific vocabulary.

The translation is often carried out by linguists or experts in the traditional language, but who are frequently members of other communities. However, the participation of the community in the translation is a very important step in improving the scientific capacity of its members. A very good example of community participation in the translation of scientific texts is the Maori community's translation into their language of the science syllabus in New Zealand.

The struggle by Maori communities to improve their economic and social situation and the consensus about the importance of reviving the Maori language for maintaining Maori culture has motivated the organization of pre-school institutions ('nests') for teaching Maori to Maori children. The nests were organized using the traditional teaching structure in which the elders take care of the younger students in classrooms containing pupils of all ages. Maori speakers (usually the elders) were charged with teaching Maori to younger generations. This is a good example of the participation of members of traditional communities in education and shows that a community can take in hand an important educational activity.

The second step was to organize primary schools in Maori. One big difficulty was the lack of texts in Maori, in particular for science and mathematics. The New Zealand government nominated two commissions to translate science syllabi and mathematics syllabi into Maori.

The science commission was headed by a Maori expert in science instruction who did not speak Maori. The other members were teachers, scientists, experts in the Maori language, etc. All of them were Maori and spoke Maori, and all tribes were represented. The translation of the science syllabus into Maori was carried out with the idea that all the words should be Maori words and not English words pronounced in a Maori way. However, the Maori language lacks many scientific words. In this case, new words were produced using Maori word-roots and Maori rules. Each new word was discussed by members of the different tribes and by teachers that used them in the school. When the commission adopted a word, it was discussed by the Maori Council which gave the final approval after considering linguistic, cultural and religious factors. Seven hundred words were created in this way and more than 1,500 members of the Maori communities participated. The translation of the science syllabus was completed in six months.

This example shows the possibility of a massive participation in translation and the possibility of transforming the traditional language by the introduction of new words that are consistent with the traditional language. The participation of the population in the discussion about how to translate each scientific concept is a mechanism for learning about science. A new word cannot be produced if its meaning is not understood. If the scientific concept behind an English word is not understood, it is not possible to translate it by creating a new word.

I had the opportunity to participate in a field trial to translate mathematical concepts into the Maori language. I am neither a Maori speaker nor a mathematician, yet I was pleasantly surprised at how well the understanding of mathematics developed in a discussion about how to create a new word using existing Maori words. This is a strategy that can be very useful for science teaching because it allows the formation of scientific concepts using unscientific words.

The problem of bilingualism

Frequently, pupils from traditional communities are bilingual. They speak both the traditional and the dominant language. Bilingualism is not a problem if pupils are fluent in one of the two languages; however, if they are not, they have significant learning problems, particularly in mathematics and science. This situation is frequent among migrant children and children who speak a non-standard dominant language such as Pidgin English or Aboriginal English. In both situations it is very important to help the pupil develop the correct language necessary for integrating scientific and mathematical concepts.

To talk or write about abstract concepts and relationships, and perhaps also to fully understand them, depends on using carefully structured language. There is plenty of evidence that many students in school and in teacher-training courses have not acquired the linguistic skills necessary for clarifying concepts and expressing mathematical ideas (MacGregor, 1991).

Overcoming learning obstacles

Scientific ideas are frequently counter-intuitive, and cannot be understood by simple observation of phenomena: they are often beyond everyday experience (Wolpert, 1993). Moreover, the development of scientific and technical literacy cannot be obtained through a simple transmission of information, and listening to or reading scientific texts is not sufficient for building basic scientific knowledge and developing a basic scientific capacity. These objectives require a long and difficult series of co-ordinated learning activities. The basic assumption regarding the didactic approach is that a learning process is not a simple acquisition of new information, but a complex process of transforming conceptual frameworks by reorganizing old concepts and elaborating new ones.

To learn something is to introduce a new element into an existing cognitive system, leading subsequently to a reorganization. The cognitive system gives significance to new information and integrates it into a new totality. If the cognitive system is not capable of incorporating new information, it is impossible to learn the associated concepts. Learners often have difficulty understanding scientific concepts because they do not have the necessary conceptual, logical and linguistic background. They have 'learning obstacles' (Gagliardi, 1991, 1994; Gagliardi & Alfthan, 1993) that can be affective (the knowledge conflicts with their beliefs), cognitive (they lack the necessary conceptual background), logical (they lack the necessary logical capacity) or religious. All these obstacles should be considered in the elaboration of educational programmes and in teacher training. It is also very important to consider the characteristics of the community, its culture, religious beliefs and methods for transmitting information and education. The success of an educational programme will be greater if it is adapted to all these conditions.

To identify learning obstacles it is possible to apply a method developed in social psychology and used in science teaching, called 'analysis of learner's representations' or 'analysis of learner's conceptions'. The objective of this method is to understand the knowledge and beliefs a person has about a particular subject. The method consists of analyzing the answers to a few questions and deducing the knowledge, beliefs, structure of causality and logic used in the answers.

If the teacher knows the learners' capacities and learning obstacles for a particular subject, he/she can organize the teaching to help them surmount the obstacles and build new knowledge. It is important also to know the ideas, beliefs and knowledge about this subject. These elements are part of the conceptual framework. Each of these elements is called a 'representation' or 'conception'. A conception is a specific concept about a specific subject. Identification of each conception is an important activity in the organization of teaching activities.

Conceptions are elements used for the interaction between the individual and the world around him/her, and which the individual uses to build new knowledge. Conceptions are built by each individual. However, this does not mean that there are a multitude of conceptions: each individual reproduces the fundamental conceptions of the society in which he/she lives. Research in science teaching shows that people in different countries have similar conceptions. However, it is necessary to analyze the conceptions in each country because the differences can be important. The analysis of the conceptions can be part of the teaching itself.

To know the learners' conceptions is of great help because they allow teaching to be organized as a function of the specific knowledge and beliefs of the learners. The information about learners' conceptions can be used for different purposes, such as to identify learning obstacles, evaluate the teaching and employ pertinent examples for teaching. Conceptions are good indices to measure learning. If, after a teaching activity, the learners have the same conceptions as before, the activity was a failure; in other words, learning implies a change in conceptions. The analysis of conceptions in relation to one subject enables the teacher to understand what the obstacles to learning are and the possible starting points for teaching.

The motivation of learners is important for the success of a teaching activity. One way of motivating the learners is to discuss problems that they recognize as important, and to give examples with which they are familiar and can understand. In this way the teaching is pertinent for the learner.

'Structurant' concepts

Overcoming learning obstacles is a fundamental aspect of teaching. When the teacher knows what obstacles to learning a particular pupil has, he/she can organize the teaching activities to overcome the obstacles and provoke the transformation of the cognitive system. The teacher should not give much information before he/she has ascertained that the obstacles have been eliminated and the trainees can build on the new knowledge.

Instruction should be oriented to teaching a few concepts that—when internalized—transform the cognitive system and lead to a new conceptual framework, permitting further learning. I call the fundamental elements 'structurant concepts' because they define a new structure of the cognitive system (Gagliardi, 1983, 1987). When a structurant concept is learned, changes take place in the capacity of learning: it is possible to incorporate new information and build new knowledge. Simultaneously, a new capacity to observe the world develops.

The history of science illustrates very well the effect of elaborating and diffusing a structurant concept in a scientific community: it shows that there are moments of great conceptual change leading to major changes in theory and research. The evolution of science is not an accumulation of data, but a series of important conceptual changes followed by changes in the way research is organized to look for solutions to new problems. In other words, a conceptual change implies a new way of thinking, new problems and new instruments to solve them. Conceptual changes are correlated with technological changes. The evolution of technology in the last two centuries illustrates how the introduction of new scientific knowledge provoked major changes in production systems.

At the individual level, the process is similar: people cannot perceive all the phenomena around them because they do not have the necessary structure to integrate the perceptions. When an individual learns a structurant concept, new phenomena can be perceived, new problems identified and new solutions sought.

The problem-solving approach

There is a paradox in learning: how can the learner build the structurant concepts if he/she has learning obstacles? There is a solution to this paradox: the cognitive activity of the learners can be oriented toward discussing problems that are pertinent for them but which they cannot solve without building a new concept. The new concept allows the problem to be solved and also provokes changes in the cognitive system: it is, in my jargon, a structurant concept. Therefore, the activity of a teacher should be to introduce problems in the mind of learners and not to introduce information. The information should be given only when learners need it, and when they ask for it to solve a problem.

Language and culture

Traditional language can be an obstacle for learning sciences and mathematics in many ways: lack of words, and differences in grammatical structure or the patterns and categories used to portray the world. Watson says:

> Language is the system of signs that we hang on nature: names that we give to natural objects and creatures, processes and relationships. People of all cultures tend to think of their own language as neutral, believing that it 'maps' the world the way it 'really' is. Yet,

scholars have suggested that languages may sometimes provide dramatically different pictures of nature, actually dividing the world differently, using dissimilar categories (Watson, 1989).

Another difficulty in teaching science and technology to traditional communities is the differences between traditional thinking and scientific thinking. Traditional communities use information at the macroscopic level: they use the information gleaned from their own perceptions, without using technical instruments to understand the microscopic or molecular level of organization supporting the visible phenomena. This information is organized in mythical structures which provide significance and organization. In some traditional cultures, such as that of Australian Aboriginals, the traditional way of thinking is a strong obstacle to science learning. Christie says:

> The units by which the Aboriginal knows his or her world are large and available to perception, for example people, trees, animals, and rocks. These are generalized into unities or cosmic entities like the kangaroo or the crow which transcend form, space, and time. The abstraction proceeds only one step from what the individual perceives, and continues to be tied to it. The connection between the perceived and the abstraction is not a logical one. For example, an Aboriginal man who says that a particular area of land is his mother is not speaking metaphorically. To him the land is his mother in a literal way most White Australians will never begin to understand. [...] all Western notions of quantity—of more and less, of numbers, mathematics, and positivistic thinking—are not only quite irrelevant to the Aboriginal World, but contrary to it. When Aborigines see the world, they focus on the qualities and relationships that are apparent, and quantities are irrelevant. A world-view in which land, spirit beings, people, and trees are all somehow unified does not lend itself to scientific analysis. [...] The Aboriginal world-view provides for the unity and coherence of people, nature, land and time (Christie, 1992).

Some of the difficulties an Aboriginal pupil has in understanding science are related to the lack of Western mathematic elements, such as numbers, in the Aboriginal language. Australian teachers are developing a new strategy for teaching mathematics, based on the capacities that Aboriginal pupils have developed (Kepert, 1993). For example, the ability to recognize the very complex and abstract systems of personal relationships in the Aboriginal community, or the knowledge about territory and the capacity to situate oneself in it. To teach fractions it was proposed to use as examples clan organization or the traditional way of cutting a fish into three parts. Using these strategies, Aboriginal pupils show the same or greater mathematical aptitude as that of pupils from Western communities.

Magical beliefs and taboos

Each community has developed knowledge, skills and practices useful for ensuring its livelihood and survival. Communities also develop beliefs related to their activities. Traditional knowledge and beliefs are transmitted from generation to generation, and can be both a positive and a negative element in science and technology training. They provide a basis upon which to build new knowledge, yet they can hinder new learning and the undertaking of new activities. Training programmes should therefore try to reinforce empirically correct knowledge and skills while helping people to abandon unscientific beliefs. People can be encouraged to abandon unscientific beliefs by making use of other beliefs. For example, religion was used in a successful educational campaign to promote rat control in Malaysia. Farmers believed that rats would take revenge upon their dead by causing worse damage. Citations from the Koran such as 'the more rats you kill, the more you will be rewarded in Heaven' and 'as a Muslim, it is sinful to be superstitious' were used by religious leaders in Friday prayers, in leaflets and on radio spots (Food and Agriculture Organization, 1987).

In Kenya, excessive wood-cutting has resulted in deforestation and is forcing women to spend several hours a day collecting wood further and further away from their homes. A programme of afforestation has been implemented to reduce the need for women to undertake this arduous and time-consuming work (Obel, 1989). The programme has also generated new economic activities, such as growing fruit and extracting wood from the forest. Other benefits have been greater biodiversity and improved working and living conditions as the forests give shade and reduce temperatures. But the programme has met cultural resistance; in some regions, planting trees is considered an essentially male activity and taboos prevent women from engaging in it. Beliefs that the trees will die, that the woman will become sterile, or that her husband will die if she plants a tree are examples of such taboos. They favour the traditional view that men alone can own land, and that if women own trees they might then claim the right to the land. Some women have overcome these taboos, using young men to do the actual planting of trees while they undertake all the other forestry tasks.

Pupils that live in urban areas but maintain some traditions also have taboos that are obstacles to the learning of science. For Aboriginal girls it is very difficult to discuss subjects related to sexual education if the courses are given by men. Information about the body and sex is taboo. Teaching about this subject is usually done by elder women in the family, and therefore men should not be present in a course about sexual education addressed to Aboriginal girls.

Temporal organization

A major problem in introducing new techniques into a traditional community is the kind of temporal organization with which members of the community are familiar. Temporal organization is linked with the perception of time as well as perception of planning, organization and achievement of activities.

Edward Hall, who analysed communication problems between cultures, discusses two main cultural systems:

The first, the 'monochrome system', is characteristic of highly developed societies where the organization of time is rigid—one thing at a time—and specific value is given to time ('time is money'). The perception of time is precise. Activities are organized following a precise temporal measure (days, hours, minutes). In this system the accomplishment of activities takes priority over social demands. This system favours the planning and achievement of new techniques.

The 'polychrome system' is characteristic of societies with a high degree of conviviality, where social and family relationships are most important in the accomplishment of activities. In this system it is possible to perform several activities simultaneously, and time is not a value in itself. This temporal system is not favourable for the planning and application of new techniques if they involve a rigid temporal organization (Hall, 1974, 1987).

When teachers work in a community with a polychrome system, they should be aware of its characteristics and of its advantages/disadvantages for the organization of teaching activities.

The main advantage of a polychrome system is the highly-developed network of social relationships that can ease the diffusion of information. Another positive characteristic is the conviviality that stimulates participation of community members in teaching activities. One negative characteristic is the fact that the polychrome temporal organization is contrary to the introduction of some of the new technologies.

The necessary changes in temporal organization and perception are an obstacle to the use of new techniques. Temporal organization is linked with psychological structures internalized in the first years of life and is essential in the establishment of relationships between the child and society. These structures do not change easily. Therefore it is not useful to talk about the need of 'working fast' or to discuss the need to avoid interruptions. For example, a main element in food conservation is reducing the action of micro-organisms by reducing the duration of some steps in the processes. Observation of some polychrome communities shows that food conservation activities are frequently delayed by social activities, such as talking between friends. The delay provokes an important loss of quality in food products, with a consequent reduction of value and an increase in health risks. Any course about food conservation should consider the polychrome approach and convince the community about the necessity to work as fast as possible at some stages.

The need for a new temporal organization may be discussed in a practical way, for example, by analysing the duration of each step of the proposed activities. Science and technology instruction can also discuss the necessity of planning productive activities and the consequences that a polychrome approach has on the quality of products. The participants are possibly not aware about the time spent in activities other than those related with production. The analysis of one's own activity can be a good way of showing the need to avoid lost time in processing activities.

Multicultural education and teacher training

Science teaching addressed to traditional communities is a particular case of multicultural education. As in any other case of multicultural education, the role of the teacher is fundamental. Science and technology teaching for traditional communities cannot be improved if general issues of multicultural education are not considered. A synthesis of the issues follows (Gagliardi, 1994):

Multicultural education is a way of reinforcing the cultural identity of pupils from all communities, including minorities. It stimulates the pupils' self-esteem by developing their knowledge about the characteristics and achievements of their own community. It also enables negative attitudes towards other communities to be overcome through awareness of their characteristics and achievements.

Utilizing cultural and language diversity is frequently considered a negative element in education. However, it can be a resource in classroom activities if teachers are capable of accepting pupils' conceptions and knowledge and can stimulate pupils to share them. Pupils' family life, cultural background and experiences can be important resources for teaching. This approach stimulates pupils' self-esteem and can help them surmount shyness and discriminatory feelings by developing mutual understanding and solidarity between pupils from different communities.

Differing educational objectives among communities. Monocultural education sets homogeneous educational objectives for the whole population. However, different communities can have different educational objectives. To accept these differences and to adapt schooling to them is an important issue for schools in multicultural contexts. This can be a difficult point when communities have very different objectives. In this case a 'bicultural school' seems a possible solution. Teacher training should include information about the educational objectives of the different communities and how to integrate them into curricula.

Teacher ethnocentrism. It is necessary to help teachers to surmount ethnocentrism and negative attitudes about minorities. These are an obstacle to understanding the pupils' cultures and accepting pupils' particularities. The analysis of teachers' conceptions and attitudes concerning pupils' communities is an important factor when organizing teacher training for multicultural/intercultural education.

Considering each pupil. Multicultural/intercultural education requires a particular capacity to adapt teaching to pupils' characteristics in a learner-centred approach. Some teachers' conceptions and attitudes concerning teaching and learning can obstruct the development of this capacity. For example, teachers frequently think that 'to teach' is identical to 'transmit information' and to learn is equivalent to 'listen and remember'. These teachers are not very concerned by pupils' characteristics and they do not adapt teaching to pupils' learning difficulties. Teacher training should help teachers modify these conceptions and develop consideration for pupils' characteristics and learning difficulties. Analysis of teachers' conceptions and attitudes about teaching and learning is an important element in teacher training.

Adapting to pupils' difficulties. Understanding the pupils' learning difficulties is a fundamental element in any educational activity, particularly when the teacher comes from a community different from that of the pupils. The analysis of pupils' conceptions and attitudes is an important component in a learner-centred approach. Teacher training for multicultural/intercultural education should include methods for analyzing pupils' conceptions, attitudes and learning obstacles, and should develop strategies and methods to help pupils overcome them.

Taboos and rules of communication. Frequently, teachers have problems communicating with pupils from different cultures. If teachers do not know the basic rules of communication used by pupils, they can have difficulties in establishing good relations with pupils. Another related problem is caused by pupils' taboos: if teachers do not take into account pupils' taboos, they can hurt the pupils' feelings and provoke a sense of rejection. Teachers in multicultural contexts should learn and use the communication rules of the pupils' communities and should be aware of pupils' taboos, adapting their activity to them.

Family participation in school activities is an important element in the pupils' achievement. Teacher training should develop the capacity to establish good communication with the families of pupils from different communities and to stimulate family members to participate more actively in school activities.

Multicultural training materials. Training materials are frequently monocultural, presenting only a dominant ethnic and cultural model. This kind of material may hurt the feelings of minority pupils and can reinforce discriminatory conceptions and attitudes. Multicultural education requires training materials which present all cultures and the history of all communities. Teachers should be trained in the production of multicultural training materials.

Conflict management. Teachers should be trained in education for conflict management. This training provides teachers with concepts and methods for developing the pupils' capacity to manage conflicts. Such methods also stimulate pupils' active participation in the peaceful solution of conflicts between communities.

Adapting to individual and community change. Frequently, traditional communities suffer major changes provoked by their relationships with Western civilization (migration, changes in languages, changes in life styles, etc.). The changes are not identical in all the members of the community and some members undergo more change than others. Pupils are not similar; it is not enough, therefore, to adapt teaching to community characteristics. Successful teaching requires adaptation to each pupil and avoiding stereotypes about the community.

The necessity of educational research

Science and technology teaching for traditional communities requires precise information about pupils' communities. This information should be updated continuously to keep abreast of the cultural, social and economic changes in the different communities. Research on obtaining and updating this information should be carried out at the local level. The information obtained should be incorporated into teacher training and transmitted to teachers. A well-organized system of research and transmission of information is an important element in multicultural/intercultural education.

Another necessary piece of information in multicultural contexts concerns the main learning obstacles of pupils. As already stated, this information is necessary in order to adapt teaching to pupils' difficulties. Comparative educational research should be organized to obtain this information.

The teacher as researcher

The problems mentioned above are difficult to solve. They require information about pupils and about their communities. However, communities and pupils change, and new information therefore becomes necessary. This situation can be resolved if teachers have the capacity to analyze their pupils in an ongoing manner, adapting their teaching to the transformations observed. In other words, teachers should be researchers in the classroom, analysing pupils' learning obstacles and using strategies and materials adapted to them. Teachers in multicultural contexts should not only be capable of establishing good communication with their pupils, but should also have an open mind and a scientific approach to teaching. Our experience shows that teachers can both develop these attitudes and capacities, and gain from analysing pupils' conceptions and attitudes.

Synthesis

— Science and technology teaching should permit traditional communities to develop a capacity for solving basic problems related to their quality of life.
— Science and technology teaching should permit members of traditional communities to overcome their low self-esteem.
— Traditional knowledge and technologies can be used in science and technology teaching. This strategy facilitates the teaching and permits the maintenance of useful knowledge and technology.
— Overcoming the gap between 'traditional' and 'scientific' thinking should not destroy traditional cultures and languages. This is a very difficult question: How does one develop scientific and technological capacities without destroying traditional culture?

— Teaching materials should be adapted to the culture, knowledge and communication characteristics of traditional communities and should not reinforce low self-esteem.

The teacher who teaches pupils from traditional communities should:

— Understand the communication rules and taboos of the community and be able to use this information in teaching;
— Be familiar with traditional knowledge, and the ways of transmitting it (tales, proverbs, etc.), and use this in science teaching.

Pupils from any community have learning obstacles. Pupils from traditional communities have obstacles similar to those of Western pupils, plus other specific obstacles. Some learning obstacles of pupils from traditional communities are:

— lack of mathematical and scientific elements in traditional language and culture;
— problems in language development, particularly for bilingual pupils;
— taboos;
— low self-esteem and feelings of not being capable of learning scientific knowledge;
— lack of family support for learning;
— low social and economic status;
— a traditional way of thinking in terms of magic, that is, a tendency to give magical explanations to observed phenomena;
— lack of knowledge about the microscopic level of organization and non-visible phenomena.

Improving science and technology teaching to traditional communities requires information about culture, traditional knowledge, the way of thinking and the specific learning difficulties. However, this general information should be complemented with information about the specific difficulties of each pupil to help him/her solve concrete cognitive problems. Teachers working in traditional communities should be able to organize research in the classroom to analyze pupils' conceptions and attitudes and learning obstacles. These teachers require additional information about each community's characteristics.

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