Teaching Science to Language Minority Students in Elementary Classrooms

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This article proposes a number of language and science related teaching strategies that are appropriate for elementary science teachers working with language minority students. Each of the nine strategies proposed are described and their theoretical underpinnings discussed. When appropriate, classroom examples are given. Commonly held teachers' beliefs (about language and science) are discussed, as these beliefs are sometimes contrary to the theoretical underpinnings of alternative strategies and impact negatively on their implementation in the classroom. It is hoped that this approach will allow teachers to reflect on their classroom practice not only in terms of teaching strategies but also by considering how their own beliefs guide this practice.

Introduction

Across North America, elementary classrooms are becoming more diverse linguistically and culturally (Atwater, 1994; Crandall, 1993; Kauffman, 1995). Some authors have suggested that by "the year 2000, the majority of children in major metropolitan area schools will most likely be language minority students" (Crandall & Tucker, 1990, p. 188). At the present time, many of these children are placed in transitional or maintenance bilingual education programs. Others attend mainstream English classrooms where they might be offered ESL activities on a pullout basis, as well as some frequent immersion programs or sheltered English classrooms (Malakoff & Hakuta, 1990). Although these programs vary considerably in their goals and approaches, in all of them, some of the content areas such as mathematics, science or social studies are commonly taught in English (Carrasquillo & Rodriguez, 1996; Spurlin, 1995).

Among these content-areas, science is commonly thought by many to be particularly rich and well suited for language minority

students (Curtain & Pesola, 1988; Ovando & Collier, 1985). As Kessler & Quinn (1987) suggest "a process oriented science class using an inquiry approach is among the optimal sources of social interaction and language input for facilitating acquisition of a second language" (p. 56). On the other hand, science is seen by many as a difficult topic to teach and to learn. Indeed, in too many elementary classrooms "Science is a low priority and is taught poorly" (Raizen & Michelsohn, 1994, p. 2). Many researchers have deplored the state of science education and insisted on the need to drastically improve scientific literacy among students in general (Fraser & Walberg, 1995; Rutherford & Ahlgren, 1990). This applies even more to language minority students. Not only are these students dropping out of high school at a higher rate than the rest of the school population, the relative percentage of these students enrolled in science, mathematics and engineering courses at the university level remains low (Barba, 1995; Rosenthal, 1996). Further, language minority people are generally underrepresented in the science and technical work force.

Though a detailed exploration of the possible causes of this complex state of affairs is beyond the scope of this article, the situation certainly does not result from a lack of effort on the part of researchers or a shortage of resource materials for teachers. As a matter of fact, there is an abundance of material on teaching science to language minority students. Numerous research articles have been published on various aspects of teaching and/or learning in this context (Kessler & Quinn, 1987; Ovando & Collier, 1985). Many books on the integration of language and content (including science) have been published (Cantoni-Harvey, 1987; Carrasquillo & Rodriguez, 1996; Crandall, 1987; Curtain & Pesola, 1988; Enright & McCloskey, 1988; Padilla, Fairchild & Valadez, 1990a, 1990b). Entire science programs have been developed, piloted and successfully implemented (Crandall, 1993; Spanos, 1989; Warren & Rosebery, 1991). Training manuals and practical guides describing effective teaching approaches and strategies are available to science teachers (Burkart & Sheppard, 1995; Cuevas, 1990; Fathman, Quinn & Kessler, 1992; Short, Crandall & Christian, 1989). Recently, an extensive report on *Content ESL in*

the USA was published (Burkart & Sheppard, 1995; Kauffman 1995; Sheppard, 1995). All of these materials contain the essence of what is known about teaching science to second language learners.

In this article, we will present an overview of some of the teaching strategies that are considered to be the most appropriate for elementary science teachers working with language minority students. First, these strategies will be described and their theoretical underpinnings will be discussed. When appropriate, classroom examples will be provided. Commonly held teachers' beliefs (about language and science) will also be considered as these beliefs are sometimes contrary to the theoretical underpinnings of the proposed strategies and impact negatively on their implementation in the classroom.

A focus on the teachers' beliefs behind the strategies implemented in their classrooms is considered to be an essential component of thoughtful teaching and an integral part of the process of teacher change. Numerous studies have illustrated how the implementation of teaching strategies is influenced by teachers' beliefs about subject matter and learning (Laplante, 1997; Lederman, 1992; Lyons, 1990). It follows from these studies that, whenever alternative teaching strategies are proposed, teachers should be encouraged to reflect on the congruence of their beliefs with the theoretical underpinnings of the proposed strategies. Without such reflection, it would be most difficult for those teachers who view science essentially as a body of knowledge to be memorized by students, to consider the implementation of a collaborative inquiry-based science program in their classrooms because their own beliefs are in direct conflict with the theoretical underpinnings of such a program. On the other hand, studies have shown that when teachers are encouraged to reflect critically on their practice, and supported in their effort to do so, changes are possible (Tobin, 1995; Warren & Rosebery, 1991).

Integrate Science Instruction with Language Instruction

Language minority students learning science in English are facing a dual task, that of learning the language in which science is taught

and, simultaneously, that of learning science related content. Their teachers are facing a dual task, that of teaching language as well as science. The first strategy discussed here addresses this issue. The other strategies presented later in this paper are more specifically related to either language instruction or science instruction.

Integrating science instruction with language instruction is at the base of any successful science program for language minority students. Practically speaking, this means that some of the classroom time allotted to language arts can be combined with that of science. For elementary teachers, this is relatively simple as they are often responsible for most subject areas in their classroom. This will provide teachers with more instructional time for science and for language. More importantly, teachers can use language related teaching strategies and methods during science instruction.

Some teachers would argue that science instructional time is quite limited and that there is a vast amount of material in the curriculum. They believe that they have to cover it all. Their students may be struggling, but these teachers do not see how they could spend any more instructional time on science. For them, integrating language and science is not an option because they see these two subjects as different and somehow unrelated. If they do integrate them, then their effort is often limited to the introduction of basic vocabulary terms.

Lemke (1990) helps us to see science as language. He suggests that "learning science means learning to *talk* science" (p. 1). "Talking science means observing, describing, comparing, classifying, analysing, discussing, hypothesizing, theorizing, questioning, challenging, arguing, designing experiments, following procedures, judging, evaluating, deciding, concluding, generalizing, reporting ... in and through the language of science" (p. 1). Students talking science have to successfully perform the science processes listed above relying on various cognitive skills, with language playing an essential role. To perform these processes, students must not only understand the scientific concepts involved and know the related vocabulary, but they must also be able to use the required language structures and manipulate the appropriate discourse features. In other words, they

must be able to utilize the various genres of science. For example, to be able to describe (in these words) a sample of pink granite containing coarse crystals of pink feldspar, medium size grains of smoky quartz and small flakes of black biotite, students must understand concepts related to rock types, minerals and grain size. They must possess the vocabulary necessary to describe the essential physical properties of rocks, such as type, grain size, shape and colour. They must also be able to present all this information in the proper sequence and use an acceptable sentence structure.

Students have to develop an appropriate level of proficiency with academic language or what Cummins calls a "cognitive-academic language proficiency" (Cummins & Swain, 1986, p. 15). This proficiency is distinct from the proficiency with social language they might already possess (Burkart & Sheppard, 1995). Even for language majority learners, the task is difficult to manage without specific language-related instruction (Rutherford & Ahlgren, 1990). For second language learners, it is only achievable through specific language related instruction.

Snow, Met, and Genesee (1989) have helped to further conceptualize the dual tasks that learners as well as teachers are facing by suggesting that "for every topic or concept, certain language is essential or obligatory for understanding and talking about the material. Content-obligatory language objectives are both structural ... and functional" (p. 206). They further suggested that one of the tasks of the teacher is to plan and implement language teaching strategies that will address the needs of the students with regard to these language objectives which are not limited to vocabulary but also include language functions.

Considering the complexity of the language demands facing all science learners, integrating language and science instruction when working with second language learners is not only a practical alternative, but probably the only alternative (Spanos, 1989). By doing so, teachers have more time at their disposal to teach science. They will be able to adopt approaches and implement strategies that are known to be favourable to second language development as well as

science learning. As suggested by Lemke (1990), if science is a language and learning science is learning to talk this language, in a way, what we know about language learning is also applicable to science learning. Teachers should see the implementation of the following four language related strategies as teaching language as well as science. These strategies are: (a) adopting a whole language approach, (b) promoting a language environment favourable to second language development, (c) introducing and formally teaching new vocabulary words, and (d) teaching the minor and major genres of science.

Adopting a Whole Language Approach

Science teachers should adopt a whole language approach for their science instruction. Some of the distinctive teaching methods of this approach can easily be implemented. These include talking and writing about previous experiences (activities and experiments), individual or group reading of non-fiction texts, book talks, student dictated stories and texts, collaborative and process writing, and working on personal word lists. The focus of these methods would be the science theme being studied. Furthermore, many of the key instructional criteria characteristics of the whole language approach find their expression in some of the teaching strategies described elsewhere in this article. *Collaboration* between learners and teachers and *purpose* are evident during inquiry-based science activities. Students' *previous experience* is at the heart of the constructivist orientation adopted in science. *Support* is behind many of the second language instructional strategies described here. Finally, *integration* is illustrated in the integration of language and science (Enright & McCloskey, 1988).

Some teachers might believe that although language is a complex system, it can be fragmented into a number of different processes and abilities consisting essentially "of a set of simple skills which can be separately mastered" (Mayher, 1990, p. 51). These teachers believe that the most efficient way "to learn to read and write [is]

through exercises, drills, workbooks, and other dummy-run activities"
(Mayher, 1990, p. 36). They see language as a noun, rather than a
verb. Children in their classrooms might have few opportunities to
actually do language.

Language (just as science) is a complex meaning making system,
incorporating various modes (listening, talking, reading, writing and
thinking), which are used to perform a number of different functions
(interactional, heuristic, imaginative, informative, etc.). As such, it
is greater than the sum of its parts. It is best experienced as a whole,
as a process rather than a product. Language is most effectively learned
when it is the vehicle of instruction; when students use it as a tool to
create and share meaning in authentic and interesting learning
situations (Cantoni-Harvey, 1987; Curtain & Pesola, 1988; Enright
& McCloskey, 1988). In other words, children learn language when
they actually use it to think and communicate in meaningful situations
(Crandall, 1993). For these reasons, it seems essential that science
teachers who work with second language learners subscribe to the
major theoretical assumptions of the whole language approach,
implement many of its teaching methods and adopt its key
instructional criteria (Enright & McCloskey, 1988).

Promoting a Language Environment Favourable to
Second Language Development

The language environment created during science activities
should be favourable to second language development (SLD). In such
an environment, learners are provided with numerous opportunities
to actively construct meaning from the language input they receive
from others, through their own meaning-making process and through
interaction and negotiation of meaning when necessary. Snow (1990)
describes some of the strategies used by immersion and second
language teachers to help students transform the linguistic input they
receive into comprehensible input. These strategies include the
extensive use of teacher talk, body language, explicit language
modelling by the teacher, realia, visuals and manipulatives in learning

activities. These teachers also establish predictable instructional routines and build redundancy into their lessons. The implementation of these strategies greatly facilitates the students' task in constructing meaning.

But some teachers might believe that to promote SLD among their students, it is essentially sufficient to provide their students with comprehensible input (Krashen, 1981). Correspondingly, they take a number of measures through which "input is made comprehensible" (Short, Crandall & Christian, 1989, p. 5) without fully realizing that it is the students themselves who actually construct meaning to comprehend any given situation. These teachers might downplay the importance of interaction in classroom exchange. Furthermore, some teachers might not fully comprehend the role played by this interaction and the importance of pushing the students to produce "comprehensible output" (Cummins & Swain, 1986, p. 133).

Teachers who adopt an interactionist view of language believe that two components of the language environment are essential to promote SLD: interaction and comprehensible output (Cummins & Swain, 1986; Wells & Nicholls, 1985). These teachers realize that meaning is jointly constructed through the interaction taking place between the speakers. In a conversation, input is often made comprehensible through a collaborative effort of negotiating meaning (Snow, 1990). Swain (Cummins & Swain, 1986) believes that this interaction can play another essential role. She argues that it is only when students are forced through interaction to produce comprehensible output, that is, negotiate the meaning as well as the form of their output, that they "move ... from a purely semantic analysis of the language to a syntactic analysis of it" (p. 136).

Teachers with an interactionist view of SLD take specific measures to promote interaction in their classroom and encourage the production of comprehensible output. Some of these measures are discursive in nature: questioning, drawing on students' background knowledge, using clarification and comprehension checks, paraphrasing, enriching and elaborating students' utterances (or asking students to do so), as well as encouraging students to negotiate the

meaning and form of their linguistic output. Other measures, affecting the organization of the classroom, include group work during activities and class-wide presentations, discussions and debates.

Introducing and Formally Teaching New Vocabulary Words

When exploring science related themes, new words (such as "food chain") or ordinary words used in an unfamiliar way (such as "energy") are often required to define concepts, name and describe objects, or explain phenomena under study. The students' needs in this regard should be addressed.

Some teachers might believe that because they work within a communicative context, new vocabulary words do not have to be formally taught, that students will understand the meaning of these words from the context and will use them appropriately when needed. Other teachers might believe that if they provide a list with all the new words right at the beginning of a new unit of work and, somehow, "explain" the meaning associated with these words, students will be able to use them when required. As suggested by Saville-Troike (1984), "vocabulary knowledge in English is the most important aspect of oral English proficiency for academic achievement" (p. 216). Considering the large number of technical terms used in science, it is unrealistic to expect students to acquire them without any formal teaching in a purely communicative context. However, simply providing a list of new words at the start of a new unit, before there is a real need for them and without their associated meanings, is not satisfactory. It would be difficult for students to understand the meanings of words such as "magnetic pole" or "chemical properties" before they have had some hands-on experiments where these concepts come into play. It is only through such experiences (with concrete objects, pictures and visuals), followed by discussions that the scientific meanings of such words can be constructed (Fathmann, Quinn & Kessler, 1992).

Ideally, new vocabulary words should be introduced only when needed to clarify thinking and promote effective communication

(Rutherford & Ahlgren, 1990). When introducing new words, whether in planned or unplanned teaching episodes, it is essential to clearly and effectively convey meaning to the students, and then, to check for their understanding. Finally, to consolidate their learning, students should be able to meaningfully reuse the newly acquired terms in different contexts (Seal, 1991).

Teaching the Minor and Major Genres of Science

As already discussed, talking science involves using the specialized language of science to observe and describe various objects of study, to hypothesize, theorize and explain natural phenomena, as well as to understand scientific texts and share findings (Lemke, 1990). These various processes of science are intricately linked with language, and constitute the various genres of science. The minor genres correspond to academic language micro-functions such as defining a concept, describing an object, and explaining a phenomenon (Kidd, 1996). The major genres, such as lab reports or research papers, correspond to academic language macro-functions. They "are usually longer, more complex, and more specialized to the work of science" (Lemke, 1990, p. 171). These genres must be formally introduced and taught to students if they are to develop the ability to use the specialized language of science.

Some teachers might believe that children will simply learn how to observe and describe rocks, plants, or animals if they are given the opportunity. These same teachers might also believe that students ought to be able to use scientific language to write a definition or produce an explanation without formalized instruction about these specific language functions. Although they might give guidelines related to the content of specific sections of a lab report , they might not realize that they need to actually teach students how to use language within each of the given sections.

The most effective way for students to learn how to talk science is to actually practise talking science. Unfortunately, in many classrooms, students are not spending much time actually talking

science and, when they do, "teachers tend to leave much of the semantics and grammar of scientific language completely implicit" (Lemke, 1990, p. 170). Kidd (1996) concurs and suggests that it would be quite unreasonable to think "that ESL students automatically acquire control over macro-functions through linguistically unguided participation in content-area work" (p. 299). In other words, students should not be expected to discover for themselves how to function successfully within each of these genres. Among other things, students should be shown through modelling and actual practice how to combine new science words into complex, syntactically correct sentences, to successfully perform various language micro-functions. They need to learn how to translate their expressive or colloquial language into scientific language. They should be shown how the minor genres relate to the major genres of science. They should be taught how to write a lab report, not only learning the details of each component but also having ample time to actually write such reports (Lemke, 1990). Eventually, students should learn some of the more advanced language structures and discourse features used in science (Spurlin, 1995) and develop a metalanguage to talk about the various language functions or genres used in science (Kidd, 1996; Lemke, 1990).

Implementing the language related teaching strategies described above will lead to the elaboration of a language environment favourable to SLD where it will be feasible to simultaneously implement the following four science related teaching strategies: (a) adopting a constructivist orientation in teaching, (b) focusing on major conceptually based themes, (c) reflecting the nature of science in the learning activities, and (d) adopting an approach sensitive to the cultures of the students.

Adopting a Constructivist Orientation in Teaching

Science teachers who adopt a constructivist orientation acknowledge "the significance of students' preinstructional conceptions [or prior knowledge] in the learning processes" (Treagust,

 Duit, & Fraser, 1996, p. 7). In their classrooms, students' ideas about topics under study are taken seriously; they are discussed and often challenged. Scientific views are presented. Similarities and differences between them and the students' ideas are explored (Hewson, 1996; Lemke, 1990). These teachers view their students as constructors of their own knowledge, as a result of their own meaning making activity while experiencing various phenomena and interacting with others (Driver & Scott, 1996; Hewson, 1996). Lemke (1990) suggests that this is also what scientists are doing as "in science, as in all other fields, it seems, we do not so much discover truths, as we *construct meanings*" (p. 185).

Yet, there are some teachers who adopt a realist view of knowledge. For them, scientific knowledge describes objects as they really are. They view knowledge not as constructed but as a given, as already out there. These teachers often adopt a transmission orientation in their teaching. For these teachers, verbal explanations of complex processes can be meaningfully shared with students even if the students are relatively unfamiliar with these processes. These teachers see no need to take into consideration their students' prior knowledge. If these teachers adopt a hands-on approach with their students, they expect the students to see what they, themselves, see and to *un-cover* what there is to discover.

Teachers who adopt a constructivist approach do not view learning "as a simple accumulation of information received in a relatively passive manner" (Hewson, 1996, p. 131). Rather, they see learning as "conceptual change", as a process involving "capturing new conceptions, restructuring existing conceptions or exchanging existing conceptions for new conceptions" (Hewson, 1996, p. 132). These teachers realize that "children have views about a variety of topics in science from a young age, and prior to learning science at school" (Osborne, 1985, p. 76). Any six year old has definite ideas about what is an animal or a plant and what causes rain or snow.

These views, also known as children's ideas in science, often differ from scientific perspectives "but to children they are sensible, useful views" (Osborne, 1985, p. 76). Just as scientists use their

theories to give meaning to observations, children use their views in their personal sense-making process. Teachers know from experience that discussing and challenging these views in group activities is an effective way to create sociocognitive conflict and promote conceptual change among their students. Otherwise, these views "can remain uninfluenced, or influenced in unanticipated ways, by science teaching" (Osborne, 1985, p. 76).

Focusing on Conceptually Based Science Themes

Science activities performed by the students should focus, in depth and for some length of time, on themes such as the solar system, life cycles, chemical reactions, ecosystems or space. In selecting themes, consideration should be given to children's interests and background knowledge (Hart, 1987). Learning activities should help students to develop important scientific concepts at their level of understanding.

Some teachers think that with second language learners variety is the key. They believe that if they stay on the same topic for too long, students will lose interest. The same teachers might also believe that content must be kept simple. These teachers might conduct two or three activities on the same topic, then move on to something else. Alternatively, they might present a series of interesting activities, neither thematically linked nor conceptually based. During their science classes, knowledge is often anecdotal in nature and close to common sense. Little effort is made to scaffold students' ideas. In particular, students are not asked to reflect on their ideas in order to organize or expand them. Conceptual development is not promoted.

There are numerous reasons why teachers should focus on a single topic for an extended time period and explore it through conceptually based activities. This follows the broad categories under which scientific knowledge is organized within the various fields of science. Also, if learning activities are conceptually based, the students will be exposed to new scientific ideas. They will then have many opportunities to develop a deeper and more complex understanding

of a specific aspect of their physical environment. As suggested by Rutherford and Ahlgren (1990), it is better to "concentrate on the quality of understanding rather than on the quantity of information presented" (p. 185). And, for second language learners, the advantages are also apparent. A thematic approach allows more time to become familiar with and practise the language functions and the vocabulary needed to talk about ideas related to the theme under study.

Reflecting the Nature of Science in the Learning Activities

Many of the learning activities proposed to the students should allow them to experience first-hand the objects or phenomena under study. Some of these activities should present discrepant events, thus challenging the students and engaging them in problem solving. Other activities should permit them to raise their own questions, design and conduct experiments, observe, classify and measure, collect and analyse data, reach conclusions and share their findings. Students should be doing science as scientists do, working in small groups, exchanging information and discussing ideas. They thus reflect the collaborative nature of the scientific enterprise. Students could be exploring magnetism with magnets and sharing their findings with their classmates. They could learn more about chemical reactions by mixing various chemicals together, researching information in books and actually talking with practising chemists.

To the contrary, some teachers view science essentially as a body of knowledge composed of facts to be found in textbooks and to be memorized by students. These teachers seem oblivious to the processes which were used in the production of this knowledge. They often adopt what is known as a textbook centred approach.

According to Trowbridge and Bybee (in Cleminson, 1990), science is "a system consisting of a body of knowledge, the process of continuous inquiry that produces that knowledge, and the scientific community of scientists that is engaged in the scientific enterprise" (p. 434). As such, an inquiry based approach reflects an essential aspect of the nature of science. Students learn to do science as

scientists do. This approach helps them to realize how scientific knowledge is actually produced. They become more rational thinkers and better decision makers as their process skills are used to deepen their understanding of scientific concepts (Hart, 1987). On the affective level, such an approach is most likely "to preserve a child's sense of wonder, joy, excitement, and curiosity" (Hart, 1987, p. 16). From a language perspective, an inquiry-based approach has many benefits. Because of a number of factors, such as hands-on materials, interaction between students, and direct cognitive involvement of all participants, this inquiry-based approach can provide a rich language environment favourable to SLD (Kessler & Quinn, 1987).

Adopting an Approach Sensitive to the Cultures of the Students

As suggested by Spurlin (1995), in classrooms where language minority students are present, "language is only a small part of the picture" (p. 71) as these students are representatives of other cultures. Culture is very much an issue. Power is also involved. Because of space limitations, these complex issues cannot be explored in detail. Yet as illustrated by Atwater (1994), Barba (1995), Lemke (1990) and Rosenthal (1996), they cannot be ignored.

Barba (1995) suggests that elementary science teachers move away from the prevalent Eurocentric/androcentric perspective of teaching and move toward a "culturally affirming perspective" (pp. 53-69). Traditionally the teaching of science has reflected an Eurocentric/androcentric world view and values. For example, "the basic assumptions of science, as it is taught to American children in textbooks" and "the basic epistemological beliefs of science textbooks are tied to a European or white male way of viewing the world." (Barba, 1995, p. 8). As suggested by Lemke (1990), science is often presented as the monopoly of people who share values such as "individual effort and achievement, attention to detail, the separation of reason from emotion, respect for authority and following instructions exactly" (pp.177-178). Also, role models presented are

mostly males of European ancestry and scientific discoveries made in South America or Africa are often ignored.

Barba suggests that teachers should become aware of how "culturally syntonic variables" can affect their students' learning. She defines these variables as the factors or influences that are in harmony with a particular culture such as the format of printed materials, the instructional language, the preferred mode of interaction, and the presence of familiar role models and cultural objects (Barba, 1995, p. 13-17). In particular, teachers should incorporate into science instruction "culturally familiar role models" (p. 16). This could be done by inviting guest speakers from the various cultural communities. In their science activities, teachers should also include objects, contexts, and environments that are familiar to the students from a cultural perspective. Teachers should provide opportunities for second language students to discuss complex ideas in their first language. This promotes better understanding (Ovando & Collier, 1985; Saville-Troike, 1984), but it also shows consideration and respect for their home language as well as culture.

Some teachers might believe that science is culturally neutral or that the world view promoted by science is universally accepted. As a socially constructed cognitive tool, science is culturally marked. Some refer to science as "Western science". According to Barba (1995), "the study of science and related technologies often requires students to adapt to a white male culture, to an Eurocentric/androcentric world view" (p. 8). Culturally diverse students often have different world views, and some of their beliefs might be contrary to those accepted or promoted by science. During classroom discussions, some of these beliefs will likely surface. Even if they do not, they still act as filters through which meaning is constructed. These beliefs can also influence how students react to various learning situations, as well as affect the students' general attitude toward science learning (Atwater, 1994; Lemke, 1990). This can create complex, problematic situations. As suggested by Ovando and Collier (1985), when it comes to cultural diversity in the classrooms "there are no immediate, absolute, or universal answers" (p. 206), but creating

"culturally affirming classrooms" is a first step in acknowledging issues of culture and power in science education (Barba, 1995).

Conclusion

The teaching strategies described in this article are thought to be the most effective in promoting science learning and, simultaneously, second language development among students. They have been selected because they respect generally accepted principles of effective learning and teaching (Fathman, Quinn & Kessler, 1992; Rutherford & Ahlgren, 1990). Also, they reflect various aspects of the nature of science and language. Some of these strategies overlap and others are intricately linked just as science and language overlap and are linked in the expression "talking science". Many of these strategies have been adopted in successful programs such as "Cheche Konnen" (Warren & Rosebery, 1991) or "Teaching Science to English Learners" (Fathman, Quinn & Kessler, 1992).

Experienced teachers of language minority students are most likely implementing many of these teaching strategies in their science classrooms. None the less, trying to implement all of these strategies simultaneously could seem to be an overwhelming task. Indeed, it would be. Their implementation is better conceptualised as a long term developmental project. Each of these strategies could be seen as an essential component of the theoretical framework needed to help teachers to reflect and improve science teaching in classrooms where language minority students are learning. After reading this article, teachers could reflect on their own classroom practice and choose one or two strategies that seem particularly well suited to their situation and implement them. As they gain experience with these new strategies and develop a richer practical knowledge of all their implications, they could implement other strategies through the same process.

In some cases, the implementation of these strategies will require teachers to acquire new pedagogical knowledge and, possibly, content knowledge in science or language. In other cases, teachers might

experience difficulties in implementing some of these strategies because the theoretical underpinnings might be contrary to their own beliefs. Adopting some of these strategies will involve re-evaluating and changing one's own beliefs. In some instances, these beliefs might be very difficult to modify because they relate to issues of power in the classroom (Spurlin, 1995; Treagust, Duit & Fraser, 1996) or because they appear to be consistent with "the dominant pedagogical orientation of North American schools" (Snow, 1990, p. 163). This is why thinking and talking about teaching strategies in light of teachers' beliefs is an essential component of thoughtful teaching and an integral part of the process of teacher change. It is also essential that throughout this process, teachers be encouraged and supported by colleagues, the school administration, parents and the larger community.

As suggested by Raizen and Michelsohn (1994), teacher professional development is a pressing issue in science education. The urgency of the situation seems to be even greater for science teachers working with second language learners (Barba, 1995; Crandall, 1993; Rosenthal, 1996).

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