Learning Mathematics in a Second Language: some Cross-cultural Issues

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Mothibi is a bright six year old and it is his first week at school. His world is that of a Botswana village and his language is Setswana[2] — a rich and powerful descriptive language that reflects the culture and traditions of the Tswana people who inhabit the region east of the Kalahari desert in southern Africa. Like children everywhere, Mothibi enters school with the accumulated experience of his pre-school years. He has already absorbed and processed huge amounts of information about the language and customs of his society and the variety of objects and experiences his environment offers: from the houses, animals and trees which have always been there, to the radios and trucks which have come "from outside" but which are now equally part of his everyday life

Mothibi's teacher has been instructed to use a curriculum which is essentially a version of the "new math" albeit dressed in a Setswana costume. Originally designed in Britain, it has been carefully translated into Setswana. The examples and illustrations have been carefully changed so as to reflect the environment and outwardly, at least, the culture of the Tswana people. so Mothibi doesn't have to construct one-to-one correspondences between cups and saucers or cricket bats and balls; instead he is to use bags of grain and storage huts, or weaver bird nests and weaver birds.

Mothibi enjoys school at first — every day brings its share of new experiences. But his teacher finds that he, like most of his classmates, is not reacting to the material in the mathematics curriculum as the teacher's manual predicted. Mothibi does very poorly on tests. He can carry out specific tasks when instructed but seems unable to make the transfers which would enable him to apply these skills in new situations. School soon becomes a threatening place, where mysterious tasks are assigned for no apparently useful reason. The best survival strategy is to stifle one's natural impulse to question and simply memorize what the teacher wants. Nowhere is this more true than in the mathematics class.

Lefa is 16 years old and is in form two at the secondary school. He is now studying all his subjects in English. Indeed, his mathematics textbook is an African edition of a British textbook series. The school authorities are very concerned because Lefa, along with most of his fellow students, is apparently progressing very poorly and is likely to fail the external examinations. Although the textbooks and the teachers manuals are designed to encourage independent thinking and discovery as a learning tool, Lefa and his classmates seem to learn only by rote memorization — and very slowly at that. On the assumption that poor command of English is the problem the school works hard to improve the fluency, reading and writing skills of the students. This seems to have little effect on Lefa's analytic skills. It does, however, speed up the rate at which Lefa can absorb material on a rote learning basis. Resigning themselves to this, the teachers rely on a rote memorization approach to prepare Lefa's class for the final examinations.

Scenes like these are repeated in many countries of the third world where teachers are striving, under very difficult conditions, to build an educational system which reflects their own culture and which will serve their society's needs. The meeting point of these problems in the case of both Mothibi and of Lefa is language — specifically the set of learning problems which can be related to the extreme difference in structure between the students' mother tongue (Setswana in these examples) and the language of the teacher. We shall elaborate this point below since its relevance may not be clear in the case of Mothibi whose teacher is a Motswana, teaching Mothibi in Setswana, using teaching materials in that language.

The basis for current mathematics curriculum planning in many developing countries is derived from the work of Piaget, Bruner, Dienes and others which have related the child's development of mathematical concepts to what are considered a "normal" progression through the stages of cognitive development. Piaget and his school have maintained that this progression is invariant across varying cultural and linguistic groups. However, studies conducted in a variety of settings in Latin America, Africa, Asia and the South Pacific have raised serious quesitons about the validity of this assumption. For example, Philp [1973], commenting on studies in Papua New Guinea, remarked:

> The central idea of the curriculum method, apart from its concentration on process and on discovery learning is that of abstraction. In 1966 Dienes contended that: "From results to date, there is no evidence to suggest that native children are in any sense less capable of learning mathematics than any other

[1] Supported by Grant No 461840393 of the Social Sciences and Humanities Research Council of Canada.

[2] The country is *Botswana*, the language *Setswana*. One inhabitant is a *Motswana*; the plural is *Batswana*. All these are derived, of course, from the tribal name *Tswana*

children." Later statements, principally by the teachers and members of the Department have been less optimistic and there is some evidence that, although Territory of Papua and New Guinea children are able to manipulate attribute blocks and other structured materials with quite astonishing skill and to convert this performance into pencil and paper situations, many of them are not displaying the appreciation and application of mathematical concepts which might have been expected to follow — and which had followed with Western children.

Philp's paper describes some of the research which he and his colleagues carried out in an attempt to find explanations for these findings.

In this article, I intend to focus on aspects of learning and teaching mathematics in which the "distance" between the mother tongue of the learner and the language which dictated the design of the curriculum plays a major role. We are content here to work with an extremely informal and intuitive concept of linguistic distance: it is sufficient for the major part of our work to consider that Indo-European languages are mutually "close" while as a group they are all distant from the sub-Saharan languages of Africa. In general it is likely to be easier for a student to function effectively in a second language which is semantically and culturally close to his mother tongue than in one which is remote. This closeness often, of course, correlates with geographic proximity, but there are exceptions. These are often the result of large scale movements of peoples during the colonial period. Afrikaans in South Africa and the Creole languages of the West Indies are notable examples of languages which are linguistically very distant from the dominant languages which are geographically close to them. See Dawe [1983] for a more detailed discussion of the concept of linguistic distance.

Austin and Howson [1979], reporting on the Nairobi Symposium on "Interactions Between Linguistics and Mathematical Education" organized by UNESCO, listed the following four key questions about which cross cultural issues in mathematics education in Anglophone developing countries could be organized:

1. Do the teacher and learner share the same (first) language?
2. Do the teacher and learner share the same culture?
3. Do the teacher and learner share the same logic and reasoning system? (And is this the logic and reasoning system we find reflected in mathematics?)
4. Is there a "match" between the language, culture and logic/reasoning system of pupil and teacher?

The extent to which these four concerns are interdependent is discussed below. A central point of the present paper is the suggestion that we extend all four to a broader context by including within the scope of the term "teacher" the curriculum designer, the textbook author, and all who have contributed to the instructional process. This has major implications for most third world countries. Even when instruction is carried out entirely in the vernacular, these questions will all receive negative answers if we use this extended definition of "teacher". This is due to the major influences on the design of mathematics curricula, teaching materials and methodology which have been imported into most developing countries from Europe and North America. Even though such importation, by now usually a fait accompli, is probably inevitable, perhaps even desirable, at least in the short term, it is time for educators to assess the effects of such factors on the learning process.

That any relationship exists between the effects of negative answers to these four individual questions is a consequence of what is known as the Sapir-Whorf hypothesis (or the linguistic-relativity hypothesis). Somewhat oversimplified, this is the view that the structure of a person's language has a determining influence on that person's cognitive processes. Detailed discussion can be found in Berry and Dasen [1974]. Fishman [1960] gives an excellent discussion of the position of the hypothesis within different schools of thought in both linguistic theory and cognitive psychology, and in particular discusses its relationship to the concept of linguistic distance, referred to above. Current research, based on field work in widely different parts of the world, tends in the main to discredit the hypothesis as a general description of the relation between language and thought. However, if one restricts attention to the specific cognitive skills involved in the learning of mathematics, a quite different picture emerges. Experimental studies such as those by Greenfield [1966] in Senegal, Gay and Cole [1967] in Liberia, and Philp [1973], and later, Lancy [1983] in Papua and New Guinea tend to corroborate the view that the structure of the learner's mother tongue has a strong influence on his cognitive processes such as classification and recognition of equivalences — processes which are central to the understanding of mathematical concepts — although, as Greenfield has remarked, the nature of this influence is far more complex and subtle than Whorf and his early supporters had imagined.

The difficulties children experience due to a curriculum which assumes cognitive modes differing substantially from those natural to the child may well fail to appear during the early school years. Under the adverse conditions which are all too common in third world classrooms: large class sizes, inadequate materials, erratic attendance and so on, it would be a rare teacher indeed who could keep track of individual children and untangle the factors which influence their performance. At any rate, the external constraints just referred to are a more obvious target to blame for poor performance than an unsuitable curriculum. The sitation is further complicated because poor performance itself may go unnoticed altogether. The most "testable" parts of the elementary arithmetic curriculum are capable of being "learned" by rote so well that childrens' test scores may be satisfactory even though major learning problems have already occurred. At some point during secondary school, when the emphasis in mathematics switches from "computing a number" to "solving a problem" or "proving a theorem" the rote method fails to produce the required performance levels and so the student's lack of understanding (which has been growing all along) suddenly "appears" for the first time.

Let us first agree to classify learning problems which are language related into two categories, which for convenience I will call type A and type B. Type A problems occur typically when the language of instruction (e.g. English) is not the student's mother tongue. Their severity correlates positively with the student's lack of fluency in the classroom language. Remedial strategies are linguistic, not mathematical — the treatment is to improve the learner's fluency in the instructional language. Such treatment may well be more difficult if the linguistic distance is great but is not in principle different in its nature. Type A problems may be found among francophone students in English medium schools in Canada, for example.

Type B problems result from the "distance" between the cognitive structures natural to the student and implicit in his mother tongue and culture, and those assumed by the teacher (or the designer of the curriculum or teaching strategies). Unlike type A problems they may occur among unilinguals being taught in their mother tongue. The example of Mothibi at the beginning of this paper is a case in point. In countries such as Botswana type B problems are found throughout the educational system: in the primary schools where the vernacular language (Setswana) is used, and in the secondary and university levels where the medium of instruction is English. At the latter levels the usual response has been to try to improve the learner's fluency in English. Such remediation has been singularly unsuccessful, and there seems to be little correlation between the student's understanding of mathematics (for example, as evidenced by the ability to prove theorems) and fluency in English. I would argue that appropriate remedial strategies are mathematical rather than linguistic — the treatment is to modify the curriculum and methodology to build on the student's natural modes of cognition.

Educators have tended to assume that only type A problems are significant. Indeed the existence of type B problems has been largely overlooked by curriculum developers in spite of the studies such as Philp [1973] which we have already referred to. In their design of elementary mathematics programs, it has thus been customary to ignore language factors altogether where elementary education is conducted in the vernacular and hence is immune to type A problems. At the secondary level, the tendency to think "type A" has encouraged a preoccupation with the improving of English fluency as the prime remedial strategy rather than asking if the student's own cognitive *persona* is being respected.

One can argue, of course, that the causal factors in type B problems are cultural rather than linguistic. Referring back to Austin and Howson's four questions listed earlier, such a position would give primacy to question 1 over question 2. The exact nature of the causal chain linking culture, language and cognition is obviously a deep question and one which lies at the heart of the debate over the Sapir-Whorf hypothesis. Yet it properly belongs to cognitive psychology and its direct implications for education are minimal. Indeed, for mathematical educators the crucial fact is that all these factors, irrespective of the cause and effect relationships between them, have an influence on the way in which learning takes place (or fails to take place). Recognizing this, the educational task is to unravel these influences and to design appropriate remedies for their negative effects.

To illustrate the background of type B problems, I will describe in more detail some aspects of the language and culture of Botswana. Perhaps this will put some of the difficulties which Mothibi and Lefa have experienced with the mathematics curriculum into sharper relief.

The traditional Batswana society is based on cattle herding (and to a lesser extent on settled crop raising). Batswana may own herds of many hundreds, even thousands of cattle, although in the Setswana language number words beyond twenty are so rarely used that their very existence has been doubted by casual outside observers. This is due to two related factors: traditonal taboos against enumerating objects, particularly personal or family possession, and the reservation of larger numerals for mystical or ceremonial purposes which dictate against their use by children. At any rate, one can assume that for virtually all children of school age, counting in Setswana stops at about twenty. Cattle are guarded by the boys of the village who are individually responsible for up to about a hundred head of cattle each. Thus, one would assume that there exists an elaborate tally system for keeping track of the cattle, but this is not the case — indeed due to the sort of taboos mentioned above, it is considered quite unlucky to precisely enumerate cattle, as they are the chief indicator of wealth in Tswana society. How then does the herder know if all his cattle are safely in the kraal at evening? The answer was described to me in these terms by one Motswana: "If you attended a family reunion, you would look around the room and *realize* that your cousin Jim was missing. You wouldn't have to count the people in the room and subtract from the expected number, or use a one to one correspondence or anything like that. *You would simply know.*" So too with the herdsman. He knows each animal as an individual, rather than as an element of a set (the herd) to be enumerated. This is reflected in the language, which has a extremely rich vocabulary that facilitates the accurate description of individual cattle with great economy of words.

This nominalistic attitude which populates the world with individuals rather than elements of classes is deeply ingrained in the Motswana child at an early age. I point at a dog and ask "What is that?" The child responds, not with: "That is a dog" but "That is Mofa's dog, from the hut near the well, who chases me when I go to get water" — giving a description which singles out the item in question uniquely from everything else in his universe as an individual, not as an example from a category. One could cite many other examples in which the culture and language of the Motswana child are at variance with the traditional assumptions of (Western) curriculum developers. His is a world of the present. He speaks a language rich (by our standards) in its power to describe events and objects observed in the environment, but one which lacks easy structures for describing hypothetical events or objects.

In addition to this detailed vocabulary for describing the traditional environment the language has also imported many words (mainly from English) to describe the many "outside" artifacts which are now part of everyday life: "buka" (= "book"), "sukiri" (= "sugar"), "galase" (= "glass") and so on. Nevertheless, from a "Western" perspective, Setswana is rather weak in generic nouns. Things are classified by what they *do*, rather than (as in our tradition which goes back to Plato), by what they *are*). Thus, "di jo" (food) translates literally as "things for eating", or, perhaps more accurately still, as "eats". ("di" is a plural forming prefix, while "jo" is the root of the verb "to eat"). If I point to an apple and ask "Is this food?" (a more literal translation of the Setswana would be: "Is this for eating?") the question would be meaningless. To be more precise, the meaning would change from one context to another. If the apple were sitting on the table as part of a meal the answer would be affirmative; whereas if we were outdoors playing catch with the apple the answer would be "no." If we were walking and I pointed to an apple hanging on a tree, the answer would depend on the speaker's state of mind: whether he were hungry or more inclined toward a game of catch. Contrast this with the usual classification, sorting and matching skills emphasized in the early stages of most "new math" curricula. Children are required at the very beginning of their mathematics programme to master complex hierarchies of abstraction and classification whose schemata are derived from Indo-European models. We surmise that enormous tension between the child's natural classification modes and those required in the classroom is the inevitable consequence. One result is that mathematics, even though taught in the vernacular, remains a mysterious subject, one associated in the child's mind with the foreign "outside" world.

By the time the student reaches Lefa's position in secondary school the gulf between the cognitive styles may have grown very large and appears in sharp relief when the students begin to move through the transitional stage where the emphasis in the traditional mathematics curriculum shifts from "calculations" to "proofs." Batswana students at the University level claim that they do all their mathematical thinking in English. "This makes mathematics very difficult, since I do not think easily in English, but mathematical proofs cannot be done in Setswana," reports a typical student. Whether or not the last statement is true in any logical sense, it is a most revealing fact that after 14 years of mathematical education in both the vernacular and in English, the students believe it to be true.

It is interesting to contrast this with the situation of Chinese students studying mathematics at the university level in Canada. Many of these students display a level of English fluency lower than that of a typical Motswana student, and yet their mathematical progress seems hardly impaired. When interviewed, these students claimed to do their thinking "in Chinese" and then translate their solution or proof back into English. In comparing their educational background with that of the Batswana, an interesting question arises. The Chinese students seem to have mainly type A problems. In particular, one can hardly imagine one of them stating that "mathematical proofs cannot be done in Chinese." Yet there is no reason to assume that the "linguistic distance" between Chinese and English is any less than that between Setswana and English and consequently one would expect the Chinese students of mathematics to be prone to type B problems just as the Batswana are. Two factors in their background suggest a possible explanation why this is not the case, First, their elementary and secondary education is almost entirely "localized" with curriculum designed by and textbooks written by (not just translated by) Chinese educators. Second, most of these students received their secondary education in Chinese, and, on examining a sample of Chinese students at the University of Manitoba a negative correlation between English fluency and mathematical knowledge was observed. (This appears to be caused by those who spent more time on mathematics in secondary school having spent less time on English). Doubtless other factors are involved, but these opportunities, extended over a long time period, to reconcile the cognitive modes necessary for successful mathematical understanding with those natural in their own language and to assimilate them into Chinese thought patterns must contribute in large part to the relative confidence with which Chinese students "think mathematically" in their mother tongue. It would be of great interest to know if there are measurable differences in the severity of type B problems with those Chinese students who received their secondary education in English rather than Chinese. Other things being equal, the above analysis would lead one to expect more severe problems among those educated in English.

The issues and questions raised above clearly have relevance far outside the African context. As Austin and Howson [1979] have noted, they arise in one form or another whenever there is a mismatch between the language, the culture, or the logic and reasoning system of the student, the teacher or the textbook author. Most of the research to date has been conducted by psychologists and anthropologists and has had surprisingly little impact on educators. Indeed, little concrete action at the instructional level has occurred. This is in part understandable, since the problem is most severe in those countries like Botswana which have few trained mathematics educators of their own and are still largely reliant on expatriate asssistance. It underscores the urgent need to train nationals of the country to assume the task of designing curriculum and instructional strategies which respect the natural modes of thought which arise from the language and culture of their own people.

One of the goals of such a curriculum would be to encourage the students to think mathematically in Setswana. If "thinking mathematically" requires assimilation of "western" cognitive modes and strategies then it is clear that this can only be a long term goal of the school system in a country such as Botswana. The present curriculum from primary through secondary school and university is based completely on cognitive modes derived from English (or other Indo-European languages), even though the language of instruction (at the primary level) is Setswana and the child's natural patterns of thought are derived from Setswana. What we propose is the development of an alternate mathematics curriculum which builds on the child's natural thought modes and gradually and continuously encourages the child to assimilate the cognitive skills required by the "western" curriculum to his own Setswana schemata. There should be no abrupt changes at any point, except perhaps for a switch in the language of instruction at the elementary-secondary interface. Even here one can conceive ways of making that shift gradually (as is often the case in practice, particularly when the teacher is a Motswana). These two approaches to curriculum design are contrasted in Figure 1.

	Language of Instruction	Curriculum models and strategies are derived from	Child's thought patterns are derived from
Elementary	Setswana	English	Setswana
Secondary	English	English	Setswana and (weak) English
University	English	English	(Weak) English

PRESENT CURRICULUM PLAN

Figure 1a

	Language of Instruction	Curriculum models and strategies are derived from	Child's thought patterns are derived from
Elementary	Setswana	Setswana	Setswana
		↓↓↓ gradually moving to	↓↓↓
Secondary	English (or Setswana and English)	English	Setswana and English ↓↓↓
University	English	English	Setswana (modified)

PROPOSED CURRICULUM PLAN

Figure 1b

What this points to is a model of curriculum building different from that normally assumed in mathematics. Such a model would begin from a starting point of assumptions about the learner's cognitive structures rather than from assumptions about elementary mathematics as a "given." Since the goal would be to end up with recognisable, "standard" mathematics, such a model would have to be dialectical, pulling the child's thinking toward the processes required by standard mathematics, while at the same time pulling the mathematics toward the current cognitive style of the learner. In the early years of school the gap might be quite large, and one of the guiding principles of such a model would be to narrow the gap as the child progresses. But at any rate, one would have to abandon the ideal of "doing everything the correct way" (in terms of standard mathematics) right from the start.

In the primary grades, such a design would require major changes in the curriculum objectives away from many which have been stressed in modern mathematics programmes developed since the 1960's. But we stress once more that the very nature of this type of curriculum change dictates that it must be carried out the the Batswana themselves. No expatriate advisor would bring to the task the necessary sensitivity to the cultural aspects of cognition which we have stressed above. Their input may be useful, indeed essential, but it cannot be the final determinant of the content or methodology used. It follows that the training of nationals of the country to an advanced level in mathematics education methods and curriculum design is a matter of the highest priority. Only as this is being accomplished can the curriculum design task begin

The development of such a mathematics programme should be carried out right up to the university level. A longitudinal study comparing the effectiveness of such a curriculum to more traditional (i.e. European translated into Setswana) forms would be of great interest. We have discussed this curriculum as a continuous process leading up to the university level study of mathematics. However, we believe that the type of curriculum change advocated here has major significance for the society as a whole, not just the minority of students destined for university. Indeed, it may be even more important for the majority who leave school at an earlier stage. As the influence of "western" technology impacts more and more on the daily lives of the Batswana, the type of cognitive adaptation we have discussed will grow enormously in importance. Indeed, one can argue that unless it takes place the progress of the country's economic and technological development will be severely impeded. It is absolutely crucial that the schools encourage and assist this change rather than impede it, and that they do so in a maaner in consonance with those factors which determine the cognitive landscape: the traditions, culture and language of the Batswana themselves

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..... it is not difficult to see how the traditional epistemology of practice holds a potential for coercion We need not make the (possibly valid) attribution that professionals are motivated by the wish to serve class interests or protect their special status. Whenever a professional claims to "know", in the sense of the technical expert, he imposes his categories, theories and techniques on the situation before him. He ignores, explains away, or controls those features of the situation, including the human beings within it, which do not fit his knowledge-in-practice. When he works in an institution whose knowledge structure reinforces his image of expertise, then he tends to see himself as accountable for nothing more than the delivery of his stock of techniques according to the measure of performance imposed on him He does not see himself as free, or obliged, to participate in setting objectives and framing problems. The institutional system reinforces his image of expertise in inducing a pattern of unilateral control.

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