Language and Technology in Classroom Settings for Students from Non-Technological Cultures*

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Bi-cultural educational contexts in mathematics present particular difficulties for learners from non-technically oriented cultures. In Australia, these difficulties are most evident in schools with a high enrolment of students from traditionally oriented Aboriginal communities Recent technological change in Australia has further increased the difference between the experiences of mathematical environments and activities that are available to children in the wider Australian culture and those of children growing up in traditional Aboriginal communities. In the past, schools have paid little attention to the cultural context in which mathematics is used and mathematical concepts are acquired. Curricula have emphasised an instrumental approach to skill development in arithmetic computation rather than providing children with classroom experiences of mathematical enquiry and problem solving In particular, teacher directed, instrumental approaches have generally provided few opportunities for meaningful discussion of mathematical activities

Education is a social process and language is the medium of communication in the classroom. The vernacular language of each culture reflects the ways in which language is used to "make sense of the world" . . to communicate between members of a group the categories and the relationships between them that form a culturally-learned consensual view of the physical environment. Language also functions at a social level as a means of defining group membership, role relationships, and appropriate behaviour. Finally, language is associated with thinking The Sapir-Whorf dilemma remains unresolved but most cognitive theorists agree with Vygotsky's [1962] position that some forms of speech are internalised in the process of conscious reasoning Language is, par excellence, the medium for social construction of both social and physical realities.

An analysis of the patterns of language use in the classroom and the potential impact of technology, as a means of providing all students with a common experience of group activity in a mathematical environment, provides some useful insights The following questions are important:

- Does the language used in the classroom provide students with information about the *qualitative aspects* of the contexts in which mathematical tasks are presented?
- What is the potential of new educational software as a culturally neutral environment for mathematical activity?

Some theoretical perspectives on culture and communication

Vygotsky [1939/62, p51] has made the following statement about verbal communication:

> To understand another's speech it is not sufficient to understand his words — we must understand his thought. But even that is not enough — we must know its motivation.

Vygotsky stresses the importance of language produced in the process of group activity in the development of consciousness He asserts that higher order concepts, such as those in mathematics and science, are developed through culturally meaningful collective activity. According to Vygotsky, when language is used to co-ordinate purposeful activity between people, it functions to achieve group consensus about the definitions of important qualitative attributes of a context, the relationship between them and also the reasons for choosing one or another course of action as a means to achieve a negotiated and mutually desired goal.

In mathematics classrooms the register of English used to discuss mathematical ideas is difficult even for children for whom it is their first (and only) language Some of the reasons that these difficulties arise are listed below:

- Lack of consensus about the meaning of words and the logical connections between them. Teachers often confuse language competence (the ability to use a word) with conceptual development
- There is an experience gap between teacher and students. As a result, students fail to understand the steps (often implicit) in a teacher's reasoning. Assumptions by teachers about mutual interpretation of a context are often unfounded.
- Students accurately interpret the function of teacher's speech as instruction and adopt a passive receptive role. Such a role inhibits creative interpretive functions that are a necessary prerequisite for discourse about mathematical contexts.

In bilingual contexts these difficulties are exacerbated Words in the vernacular often carry very different meanings and associations from their English counterparts In non-technical cultures the language forms and conceptual categories are

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often not suitable for use in some mathematical contexts. For example, English has been used for many hundreds of years to convey quantitative information about trading, industry and technology. For the Pitjantjatjara Aboriginal people in Central Australia, measurement is not an important cultural activity and quantity in precise terms is rarely considered. In social contexts in traditional communities, comparisons and individual competitiveness are viewed negatively and actively censured. Bernstein [1971, 1985] would suggest that the complex kinship system by means of which status is ascribed, rather than achieved, in Aboriginal Communities mitigates against the development and use of an elaborated language code. In any case, language is not traditionally used to convey precise factual or quantitative information. It is lacking in terms for number, numerical relationships and precise comparison. Further, children from these communities enter school with little understanding of *why* anyone counts and measures.

For the reasons discussed above, English is usually the language of instruction for mathematics at the upper levels of bi-cultural schools. However, Aboriginal English as spoken in traditionally oriented communities tends to reflect the form and function of the vernacular. Thus, for Aboriginal students, not only is English a second language but Aboriginal dialects constitute a restricted code in mathematical discourse.

Sperber and Wilson [1986, p 124] provide a detailed analysis of the effects of cultural experience on verbal communication. They suggest that when two people converse in a particular context, they each bring a subjective and individual "cognitive environment" to the task. They describe communication in information processing terms as an attempt to establish "a shared cognitive environment . . . a set of facts that are manifest to both". They stress the importance of perceived relevance in the selective process of listening to verbal information. They define relevance in terms of:

> the extent that new information easily connects with old ideas

and

> the extent that new information allows new useful inferences that were not previously possible.

Sperber and Wilson suggest that communication difficulties arise when a speaker erroneously assumes "mutual knowledge" about a context or when a listener fails to perceive the relevance of speech either because the connections between the new information and prior knowledge are not evident (require too much of a processing effort) or the importance of the new inferences that are allowed is not understood.

Research, conducted as part of the course development for the Anangu Teacher Education Project in South Australia, suggests that the interpretation difficulties described above are prevalent when traditionally oriented Aboriginal adults attempt to negotiate with people from the wider Australian culture in contexts (such as wage negotiations involving consideration of time) where quantitative reasoning is needed. Non-Aboriginal Australians often fail to make the assumptions and priorities of the qualitative aspects of the context explicit even in cases where they are aware that these are not shared. In classrooms in Aboriginal schools similar difficulties arise when mathematics curriculum materials present problem solving or enquiry tasks in "concrete" contexts in an effort to make mathematics learning more meaningful. Aboriginal people are very aware of the cultural bias of such materials and of the "non-Aboriginal" assertive behaviours required for mathematical problem solving. In many communities and several adult numeracy units there is resistance to this style of instruction. In schools with a high enrolment of Aboriginal students, the issue of value and identity conflict associated with mathematical activity is a major factor in the speech patterns for both teachers and learners.

Halliday [1974] provides a useful framework for analysis of speech patterns that takes the role relationships between speakers into account. He suggests that three factors are influential. These are field, tenor and mode. Halliday describes them as follows:

FIELD: The topic of discourse and its cultural context (including the current activity).

TENOR: The role relationships between speakers.

MODE: The function that language serves in the context.

An analysis of speech patterns in classrooms using Halliday's framework reveals considerable inconsistency and conflicting social messages. Research (Crawford [1986a, 1986b]) has formed a significant relationship between these inconsistencies, cognition and achievement.

The "field" of discourse associated with quantitative reasoning occurs in cultural contexts in which active exploration, investigation, measurement, interpretation, questioning, comparing, evaluation, hypothesis testing, explaining and justifying are also appropriate activities. Discourse appropriate to the topic of mathematics occurs naturally in contexts in which these activities are carried out by a group of people. In contrast, mathematics instruction as it is commonly experienced in schools, particularly at the secondary level, involves few of these activities. Rather, the teacher (who knows how to do a mathematical procedure) instructs the students who don't. Students are encouraged to compete with each other to demonstrate their ability to follow instructions and remember them. The teacher's language functions primarily at a transactional level [Little, 1984] in telling students *how* to carry out procedures. The "tenor" of teacher/student discourse is hierarchical. This means that the language patterns used by students reflect their ascribed subordinate role (and is a restricted code in Bernstein's terms). Interpretation, exposition, and judging are all associated with the authoritative role of the teacher. However, these teacher activities are usually covert and not made explicit through patterns of language in teacher discourse. Student speech is usually restricted to repeating instructions or demonstrating *know how*.

As the authority in the classroom context, the teacher controls not only the "field" of discourse but also the "mode". Typically, the field of mathematical discourse in schools does not include the contexts for quantitative reasoning outside school. The mode of language use functions to transmit instrumental information about procedures and rules on the part of the teacher, and to demonstrate knowledge of these on the part of the learner. To the extent that students accept their role as learners in this type of classroom context, they gain little experience of elaborated mathematical discourse (either as listeners or speakers) and little information about the qualitative aspects of the cultural contexts in which mathematical activities occur.

Language is also sometimes used to assert authority and to distance the teacher from the students. Teachers often demonstrate their knowledge of the formal mathematico-scientific register of language and implicitly their membership of an educated class in the wider Australian society. Aboriginal, and other students from minority ethnic groups, often resist such language use. Aboriginal dialects of English or vernacular languages are spoken as a means of asserting a separate identity. Bourkis and Giles [1977] have described the use of language to maintain intergroup distinctiveness.

The distortion in communication that occurs in bi-cultural situations when assumptions about the mode of language use are not understood is exemplified in the case of questioning. For Aboriginal people the teacher habit of asking questions for which they already know the answer is incongruous and offensive. The question form is not often used by people in Aboriginal communities and never in the assessment mode commonly used by teachers. The situation is further complicated by community attitudes to knowledge acquisition. Information is given and skills are taught when elders or others with appropriate status consider the context and time are suitable. Asking questions is generally considered inappropriate behaviour. Teacher questioning in school typically invokes passive resistance as a form of identity defense. Inexperienced teachers exacerbate this block in communication in one or both of two ways. If the lack of response is interpreted as wilfulness, then anger is expressed and emotional distance is created. If the failure to answer is interpreted as a sign of lack of ability, most teachers respond by simplifying and fragmenting mathematical procedures. This tends to further reduce student access to information about the meaning, contexts and purposes of mathematical activity in the non-Aboriginal culture.

Setting the social context for mathematical communication

It is clear from the above discussion that the social organisation of classrooms and the learning needs of students often place conflicting demands on language function. All too often the patterns of language use don't provide students with access to explicit information about the qualitative aspects of contexts in which quantitative reasoning commonly occurs outside school or the "concrete" contexts in which mathematical tasks are presented in schools. The tenor of discourse that is appropriate for the hierarchical relationship between teacher and students is not isomorphic with the tenor of discourse between people striving to achieve consensus about the meaning of a mathematical context. The situation is exacerbated by widely held views about the absolute nature of physical and social reality, and an over-emphasis on instrumentalist approaches to instruction. The patterns of mathematical achievement of girls and other minority ethnic groups suggest that this state of affairs is detrimental to learning. The low achievement of Aboriginal students in mathematics is a major concern for educators in Australia.

When enquiry-based teaching methods are used and students work in groups, the social context (and patterns of language use) appear likely to be similar to those occurring during collaborative mathematical activity outside school. An elaborated form of mathematical discourse is functional and appropriate in such contexts. However, the effects of variations in the "cultural capital" that students bring to schools may be exacerbated as enquiry-based learning environments place greater demands on students for interpretation of the contexts for mathematical reasoning.

In bi-cultural contexts it is essential that the social context of the classroom is structured so that different ethnic groups are encouraged to discuss differing cultural assumptions about the qualitative aspects of mathematical contexts. Once some cultural differences have been made explicit and discussed, teachers are less likely to assume that all their students share mutual knowledge of learning contexts. With a heightened awareness among teachers, students from non-technological cultures may gain access to the cultural information that makes school mathematics relevant for them.

This type of collaborative information exchange has been begun as part of the Anangu Teacher Education programme. As the mathematical component of the course has been developed it has become clear that an exchange of cultural expertise is fostered in situations where members of both ethnic groups first collaborate in mathematical investigations and then explain their findings to the wider Aboriginal community. In the sense used by Duckworth [1983] both the non-Aboriginal tutors and the students in the programme have become "learners". A number of things have become evident in the course of these investigations. First, "concrete" representations of arithmetic or algebraic expressions using Aboriginal categories and relationships are as difficult for non-Aboriginals to interpret as are the usual school materials for Aboriginal students. Second, the somewhat paternalistic management of Aboriginal communities and their transactions with the wider Australian culture "protects" members of the group from opportunities for quantitative reasoning and, as importantly, from access to knowledge about the salient qualities of the contexts in which such reasoning commonly occurs. Also, interaction between members of such disparate ethnic groups is often problematic. Sometimes it is necessary for members of both groups to defend their cultural identity. One day when an impasse had been reached an Aboriginal student was heard to observe:

> You know, the computer doesn't even know that we are Aboriginal.

For the student, interaction with a computer seemed less difficult than with a non-Aboriginal teacher.

Computer software as a medium for collaborative investigation of mathematical and scientific contents

New educational software provides a context for mathematical learning with at least four potential advantages for students from non-technically oriented cultures These are:

- An alternative focus for collaborative learning and the use of elaborated forms of language among students
- A socially neutral source of information.
- Intelligent software in science and mathematics provides students with a *common experience* of dynamic visual representations of abstract concepts and the relationship between them
- An experience of goal directed activity within mathematical constraints (a "mathetic" environment)

Firstly, it must be recognised that the recent technological advances in developed countries have resulted in pressures for change in classroom organisation and in the curricula offered in schools Increased use of information technology has lead to an increase in the incidence with which quantitative information is presented in the printed media and on video. There is a perceived need for citizens to be able to interpret such information. Nowhere has this pressure been felt more than in mathematics and science Further, in a period of rapid technological change, creative adaptability is at a premium and traditional teaching methods in which "knowledge" is transmitted from one generation to the other are no longer appropriate However, when a group of students in a mathematics class work towards a mutual goal on a computer they have common experience to talk about An important new quality of the learning experience with computers is that much student thinking that was previously covert is now represented on the screen in a visual form that facilitates critical analysis through language Silvia Weir [1987] describes the beneficial impact of a public and visual display of efforts and ideas at Hennegan school. In such a context elaborated mathematical discourse is functional Further, the information available from the computer in numerical, verbal or visual form is available to each member of the group

Microcomputers have the potential to act as a socially neutral source of information. Seeking information from a computer environment as an adjunct to learning is not necessarily plagued by the communication blocks associated with social expectations and hierarchical role relationships. Ways of obtaining information can be planned collectively and the usefulness of information obtained can be questioned without the risk of censure for behaviour inappropriate to the role relationships between teacher and student.

Michaels [1985] warns that the computer is "a dependent variable" in the classroom The changes described above can only occur to the extent that teachers are able and prepared to adapt their teaching style and classroom organisation. In particular, collaborative learning is not a necessary condition of computer use in the classroom. However, it does enhance the role of language as a medium for achieving consensus about the interpretation of learning contexts and maximises the potential of computers as socially neutral sources of information.

For students in bi-cultural contexts the changes mentioned above are important First, they reduce the extent that discourse between ethnic groups is necessary. Aboriginal adults and children report positively about this change in terms of greater security and emotional comfort In a culture that places great value on human relationships and collective activity, the misunderstandings that commonly occur during communication with non-Aboriginal people and the value conflicts that arise when new social expectations in school are superimposed on the different role expectations of the community, cause considerable strain It is possible for a group of students to relate to each other in the manner expected by the community while working with a computer and collectively completing a task. Collective discussion of a display on a monitor screen may take place in the vernacular, Aboriginal English or in a more formal register of English as the demands of the context rather than social expectations require. Second, for Aboriginal students, collaborative effort rather than individual competitiveness is consistent with community values and their Aboriginal identity. They are skilled in collaboration. Even when working with children from other cultures, collaboration enhances the role of language to clarify assumptions about qualitative aspects of any context for quantitative reasoning.

However, perhaps the most significant change in the learning environment, when computers are used in the classroom, is the external, visual representation of abstract ideas, problem solving strategies and reasoning processes that were previously covert For students in bi-cultural contexts this quality of computer-rich learning contexts shifts the field of discourse to a metacognitive level. It is possible to learn about learning . . to find out about assumptions . to know which qualities of the context are being attended to by others and why For Aboriginal students this has been the "secret knowledge" of the non-Aboriginal culture

Educational software is not culturally neutral. "Intelligent" learning environments reflect the attitudes, priorities and values of their designers. There is much variety. For example, early interactive software designed to promote drill and practice in mathematical facts reflects behaviourist views about skill development In contrast, microworlds produced by BBN Laboratories (White & Frederiksen [in press], Reuben and Bruce [1987]) use techniques for basing microworlds on qualitative reasoning through simulation of abstract phenomena in the domain. White [note 1] reports that experience of this type of new learning environment is beneficial in terms of abstract concept development in science particularly for those students with little prior experience of the simulated context. Reuben and Bruce [1987], when describing ELASTIC, an environment for learning abstract statistical thinking, state that the system's "pedagogical power will derive from new techniques for *visualising* and *manipulating* abstract statistical entities". These dynamic microworlds are designed so that they are easily manipulated and explored by students in ways that draw their attention to the meaning of visual representations presented on the screen in terms of their own experience Students using the ELASTIC system continually comment evaluatively about how much their statistical results "make sense".

The learning environments described above are designed to improve the access of students to higher order (culturally constructed) concepts in mathematics and science through new forms of visual representation of qualitative aspects of specific ideas. Other intelligent systems, such as LOGO (and most recently LEGO/LOGO), provide a "mathetic" environment in which mathematical knowledge is functional as a means of mastering the constraints of the microworld so that it can be used for a wide range of purposes. That is, the microworld directs attention to qualitative aspects of the learning environment (e.g. distance, angles, logic) which are themselves important mathematical ideas. They are investigated, discussed and understood *incidentally* as a means to achieve other goals chosen by students. For Aboriginal students LOGO also provides a spatially oriented microworld which is organised according to the geometric principles of the wider culture. In this environment effective ways of thinking about space and location using their own highly developed ethno-mathematical world view must be discarded. For some, this experience is initially very frustrating.

Each of the new systems discussed above highlights important qualitative aspects of contexts for quantitative reasoning and provides a new information-rich learning environment in which visual representation of ideas and outcomes forms a focus of a new kind for mathematical discourse at a metacognitive level. It is this type of discourse which offers students in bi-cultural contexts access to the assumptions about categories and the relationships between them that form the basis of mathematical contexts in the wider culture.

Conclusions

Students from non-technically oriented cultures have special needs for language use in mathematics whether they are fluent in the language of instruction or not. The case of Australian Aboriginals has been used in this paper as an example of the difficulties encountered in a bi-cultural educational context. However, the situation described above applies equally to all cultural groups who enter school with little experience of the cultural contexts in which quantitative reasoning is used in technical or scientific activities.

The discussion above suggests the following conclusions:

1. Students from non-technically oriented cultures do not share the assumptions about the social and physical environment that are implicit in school organisation and the mathematics curriculum.

2. Patterns of language use in the classroom are usually determined by a hierarchical and competitive social context and do not provide information about qualitative aspects of the contexts in which mathematical tasks are presented.

3. For students from non-technically oriented cultures (for example, Australian Aboriginals), lack of such information causes difficulties in the interpretation of contexts for quantitative reasoning that are reflected in low achievement. In Sperber and Wilson's [1986] terms, essential qualitative aspects of mathematical contexts, and the relationships between them are not perceived as relevant

4. The use of computers in the classroom has the potential to change the social organisation in a positive way so that language functions to inform students about mathematical contexts.

5. New intelligent learning environments foster mathematical discourse at a metacognitive level by providing a public display of ideas and representations of abstract concepts. However, computer software reflects the assumptions and priorities of its designers and is not culturally neutral.

Education is a social process and the patterns of language use in the mathematics classroom are a critical determinant of learning outcomes

Note

Personal correspondence White observes that girls in particular benefited from experience with a system that simulated electric circuits

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