Teaching and Learning Mathematics and Science in a Second or Third Language

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Abstract

Teaching and learning in a second or a third language is not an easy task. Literatures have indicated that teachers and students involved have to struggle in order to cope with a language policy that requires them to teach or learn in an unfamiliar language. There is no doubt that in the learning process, language is the most powerful tool to deliver knowledge and skills. It becomes more difficult for learning to occur effectively if the language of instruction becomes a barrier to the learners.

This study focuses on the teaching and learning of mathematics and science in English in Malaysia, where English is a second or a third language to both teachers and students. The main aim of this research is to investigate how languages are used in mathematics and science classes taught in a second or third language, and to understand how these are supported with multimodal resources. This study employed qualitative methods, involving a multiple case study and interpretive research paradigm. A number of approaches to data collection were used including classroom observations and video recording. Data were gathered mainly from classroom video-recording, supported by video-stimulated recall interviews of teachers and students, and classroom observation. Transana, an analysis software tool is used to analyse the data through a coding procedure.

One of the main findings coming out of the study concerns the usage of English. As the language of instruction, English was only used in a formal form with the support of provided resources. However, Malay and a mixture of languages supplemented the function of English in situations when English proved inadequate for meaning generation.

The next finding shows that, in most cases, English was the main language used for content related talk in which English resources such as textbook and written notes were available for the teachers. Malay on the other hand, was used for other types of talk, such as organisational, disciplinary and informal talk, as well as teacher-students interactions during group work discussion.

Another important finding of this research is the teachers' and students' choice of languages. Their choice of languages were influenced by several factors, but the major influence seemed to be the teachers' language level where language shifting in the classroom was highly dependent on the teachers' language resources needed to express complex meanings.

Finally, as the main contribution to the field, it is found that a range of modes such as gesture, visual and mathematical representations, artefacts and embodied experiences, as well as natural language, seemed to play a crucial role in the meaning making and translating process in bilingual mathematics and science classes.

This research has demonstrated in some detail the pedagogical implications of Malaysia's language policy, and by extension has highlighted some significant issues around the implementation of a policy of bilingual teaching in mathematics and science, more generally.

CHAPTER 1
Introducing the Study

1.1 Introduction

This chapter contextualizes the problem this study intends to address. First, a statement of the problem is discussed. Then, the context of the study is presented. Finally, it presents the background of the study which discusses briefly the education context in Malaysia, and the researcher's background and perspectives in relation to the proposed study.

The problem that this study addresses is the usage of languages in the teaching and learning of mathematics and science in a second or third language. Language plays a crucial role in mathematics and science classrooms, as in other subjects. Particularly, in mathematics and science classrooms that use a second or third language as the language of instruction, the language issue is seen as complicated. In first language mathematics and science classrooms, teachers and learners are required to learn the academic language of mathematics and science, which is different from everyday language. Learners in a second or third language mathematics and science classrooms on the other hand, need to deal with both the academic language of the subject and the language of instruction.

Importantly, in learning mathematics and science, learners are also expected to have the ability to understand the multiple modes of representation that are used extensively to convey meaning in mathematics and science. Contemporary research studies establish that focus needs to be given to the various aspect of representation in mathematics and science as a crucially important element of learning. A number of research studies have also identified that the representational aspect is a key difficulty in learning mathematics and science, especially to integrate and coordinate the many types and forms of representations.

Given such a context, this proposed study intends to investigate the teaching and learning of mathematics and science in a second or third language, particularly focusing on the aspects discussed above. This study examines strategies that are employed by both teachers and students in consideration of dealing with these multidimensional challenges, in their second or third language mathematics and science classrooms. In spite of the fact that many research studies have discussed various problems of teaching and learning mathematics and science in bi/multilingual settings, too little attention has been given so far to the challenges of dealing with multiple modes of representations in a second or third language.

1.2 Context of the Study

Throughout the world, mathematics and science are learned and taught in situations of language diversity. In many countries, language other than students' and teachers' first language is used as a medium of instruction in mathematics and science classrooms, due to various factors such as colonisation, migration, and globalisation.

For example, Rollnick (2000) defined two broad categories of second language learners of science. The first category is for learners who have come to a country, and learned partly or fully in another language, whereas the second category is the learners of a multilingual country which use a former colonial language as a medium of instruction at school. The ICMI (International Commission on Mathematical Instruction) Study 21 Discussion Document (Committee, December 2009) identified a number of different settings of societies around the world that learn mathematics in a language that is different from their first language. It includes societies that have more than one official language where one of them has a higher status than others, societies in which a foreign language is taught through subjects like mathematics, and societies where the language of instruction changes across primary, secondary, and tertiary levels.

With these linguistically diverse contexts of teaching and learning mathematics and science, one of the associated issues concerns the importance of language. Learning occurs in complex linguistic environments, and in these contexts particularly, complexity derives from the multiple language backgrounds, mathematical and scientific languages, and the semiotic systems that are always present. Teachers and

learners routinely find ways to discuss and learn mathematics and science, regardless of how they feel in terms of the language they use to learn.

It is also common in many countries that a global language, such as English, is associated with high status jobs or access to the dominant class (Committee, December 2009). This situation has led to pressure within the education systems to use the global language in teaching and learning. Learners then are required to switch from their main language to the global language at some point in their education. However, many learners may be ill-prepared to engage in such change.

This study sits within this globalised context to look at this issue of the teaching and learning of mathematics and science in a language that is different from the learners' first language. It intends to understand how teachers and students discuss and learn mathematics and science in such a context in terms of the language being used. As the study was done in Malaysia, which is a multilingual and multiethnic country in which mathematics and science were taught in English, the diverse linguistic backgrounds of the teachers and the students allowed a valuable insight into the ways in which they use language in their mathematics and science classrooms.

1.3 Background of the Study

This following section discusses briefly the medium of instruction policy scenario in Malaysia, as well as the researchers' background and perspective as the background of this study.

1.3.1 The Medium of Instruction Policy in Malaysia

Since its independence in 1957, Malaysia has gone through tremendous changes in the medium of instruction policy. The post-independence period led to a shift from English, the language of the colonial masters, to Malay language, the language of the dominant ethnic group[1]. In the beginning of 1957, Malay language was made a compulsory language in all government aided primary and secondary schools. Then,

[1] The focus on Malay language and English does not mean that there are no other languages. Malaysia is a multiethnic nation where other languages such as Mandarin, Tamil and a host of other minority languages, guaranteed equal opportunity under Article 152 of the constitution (as cited in Gill, 2005)

one year after independence, national secondary schools which use the Malay language as the medium of instruction, started to operate. From 1970 onwards, there was a gradual shift in the medium of instruction in the English medium schools and, by 1982, the Malay language became the sole language of instruction. In 1983, all public universities began to use Malay for all teaching purposes (Puteh, 2006).

For a period of almost thirty years, Malay language has successfully functioned as the language of education. Enormous effort and resources were spent in cultivating and establishing the Malay language, especially to enable the language to cope with the demands of the field of science and technology (Gill, 2006). English on the other hand, retained its official language status in Malaysia for only ten years after independence. After that period, English was relegated to a second language, and from a medium of instruction to a school subject (Puteh, 2006).

However, in the early 1990s, English was reinstated as the medium of instruction in higher education especially in fields of engineering, science and medicine. The change of policy has resulted in a bifurcation of the policy in higher education, whereby public institutions of higher education retained the Malay language as a medium of instruction. At the same time, private institutions of higher education were given the freedom to use English as a medium of instruction. These changes were then followed by another decision made by the government in 1993, which was to allow the use of English in science, engineering, and medical courses in universities and college. Since 1996, with the introduction of the Education Act 1996 and the Private Higher Education Institutions Act 1996, the use of English as a medium of instruction for technical areas in post-secondary courses and the latter has been approved. The move from Malay to English was considered as essential for the economic and technological development of the nation.

The Teaching and Learning of Mathematics and Science in English (ETeMS)

In January 2003, another major change in the Malaysian education system was introduced, which was the re-adopting of English language as a medium of instruction for mathematics and science in national schools. The change was implemented in a staggered fashion, beginning from Standard 1 in primary schools, and Form 1, Form 4

and Form 6 in secondary schools. The decision to take this move was underpinned by several reasons, including the ability to compete in the era of globalisation and the knowledge and information explosion in science and technology with English as the most influential lingua franca (Yassin, Marsh, Tek, & Ying, 2009). The advances in science and technology demand new skills and abilities and this has impacted on the teaching and learning process (Idris, Cheong, Nor, Razak, & Saad, 2007).

Since its implementation, many debates have been raised among the general public, parents, political parties and even teachers on the effectiveness of the policy. Many people considered this change in the language of instruction as a formidable challenge. Mathematics and science teachers faced several challenges, having to cope with the double demand of transmitting content as well as language. It poses particular challenges not only for teachers who have been trained in the Malay medium but also for those trained in English as their professional experience has largely involved them in the use of Malay language as the medium of instruction (How, Yan, Wan, & Kaliappan, 2005). On the other hand, students with low proficiency in English also faced the double challenge of learning the subject and learning the new language of instruction.

Many programs such as training, workshops, pre-service and in-service courses have been conducted as well as CD-ROM-based courseware developed by the Education Ministry to improve teachers' English proficiency and to assist with the teaching of mathematics and science in English.

The Abolishment of ETeMS

Six years after implementing ETeMS, the Government of Malaysia announced another massive change in the education system. In July 2009, the cabinet approved the Ministry of Education's proposal to abolish ETeMS, reverting to Malay language and vernacular languages in phases effective from 2012. The move would see national schools (primary level) teaching mathematics and science in Malay language, while Chinese and Tamil schools would employ their respective vernacular language. Secondary schools throughout the country will use Malay language as the medium of instruction.

This new policy would be implemented in stages at the beginning of 2012, starting with Standard 1 and Standard 4 in primary schools and Form 1 and Form 4 in secondary schools. Matriculation, Form 6 and university levels however, would not be affected with this change. To ensure that the implementation would not affect the performance of students currently learning mathematics and science in English, the teaching and examinations for these two subjects will be done in dual language until the last cohort of ETeMS ends in 2014.

Based on much research and observation, the government declared that the ETeMS policy could not be implemented to achieve its desired goal. Studies have found that only a small percentage of teachers were fully using English in the teaching of the two subjects, as was intended. Meanwhile, the primary school evaluation test results had shown a decline. Furthermore, the disparity in results between urban and rural schools was widening when ETeMS was being implemented. A Trends Report also showed Malaysian Students' position went down from the 20th place to 21 since the implementation of ETeMS ("PPSMI: 'Declining scores prompted policy reversal' ", 2009). The government also admitted that students faced difficulties in coping with English as the language of instruction, and their ability to learn the subjects had dropped.

Rather than being used as a language of instruction, the English language will continue to be taught as a compulsory subject. It will be enhanced at the school level by recruiting an additional fourteen thousand English teachers. The duration of English lessons for all levels of schooling will be increased, and interactive computer lessons will be employed.

As well as its symbolic and embodied aspects languages are framed within, and encapsulate, the ways in which the world can be understood, spoken about and behaved within. As such, language and culture are inextricably intertwined. Unequally empowered ways of thinking within communities interrelate in ways that make the formulation of national culture and identity intensely political. Processes of globalisation, colonisation and migration add new and powerful dimensions to this process and complicate the ways languages and languages education is understood and implemented (Pennycook, 1998). The increasing importance of English as a lingua franca and international language, particularly for purposes of communication,

trade and science and mathematics dissemination, adds further dimensions to this process (Crystal, 1997). In Malaysia, this interrelation has been of particular significance as British Colonisation between 1786 and 1942 has at various times made English language education both essential and something to be fought against. Historically it can be seen that English language education has been, at different times, embraced and rejected, in part as a product of this relationship.

The insight of post-colonial literatures is that the relationship between language and identity is not merely superficial. Resistance to colonialism, in Malaysia as elsewhere, suggests that people need to be able to work from outside of the structures inflicted upon it within language thinking and structures of the colonisers' language (Pennycook, 2000).

1.3.2 Researcher's Background and Perspective

In order to illustrate the personal background and perspective of the researcher, this section will be presented from the first person point of view.

My teaching background started when I was appointed as a tutor at the University of Malaya, Kuala Lumpur, in 1996. Since then, I have been teaching various linguistics and Malay language courses for undergraduate level, at two other public universities, namely the Islamic International University of Malaysia, and Sultan Idris Education University, the university where I am currently attached.

My experience of teaching linguistics and Malay language courses for almost fourteen years has motivated me to investigate the current policy, which is the teaching of mathematics and science in English, in depth. Based on a considerable number of studies, many challenges have been identified in implementing such a policy for students or teachers. Research has revealed that one of the biggest obstacles for this policy to succeed is the English language proficiency of both among teachers and learners. At the same time, many studies have been carried out to investigate teacher professional development, as well as the achievement levels and support that has been given to successfully implementing the policy.

As yet, few studies have been found that give specific attention to problems faced by learners, or specific techniques for supporting groups of learners who have difficulty in using English to learn. This seems to be a gap in this area of investigation that needs to be filled if we are to get the whole picture of the situation. More specifically, the crucial aspects of learning mathematics and science that required students to deal with various forms of languages has not been fully investigated. I believe that an understanding of the issues associated with teaching and learning mathematics and science in a second or third language issue can only increase if we try to look through the lens of the teachers and learners. A comprehensive study is needed of the challenges of using different types and forms of language in mathematics and science, if we are to understand the challenges of learning those subjects in a second or third language.

With the decision to revert the medium of instruction for mathematics and science back to Malay language in July 2009, much discussion occurred between my supervisors and I regarding the impact of this sudden policy change on my study, which was initially intended to investigate language use in the context of the ETeMS policy. By that stage however, my literature review had shown a range of global issues in bilingual teaching especially related to mathematics and science, and I had become interested in the use of representations in mathematics and science teaching and learning, a contemporary perspective receiving a lot of attention in the research literature. The fact that the policy did not begin to operate until 2012 provided a brief window of opportunity to collect data in Malaysia that related to this global issue.

In my view, this topic is relevant in both the global and national context. It could be well justified on the basis of the literature review in terms of its relevance to the global setting of bilingual education, and its innovative nature in bringing a more complex view of language into play. Ultimately, this research provides insight into the Malaysian experiment in teaching and learning mathematics and science in English.

CHAPTER 2
Reviewing the literature

This chapter reviews the relevant literature on teaching and learning in a second or third language generally and specifically focuses on teaching and learning issues in mathematics and science. Drawing from the literature on teaching and learning in other than first language from all over the world, this chapter consists of two main sections. The first section outlines the scope of second or third language learning globally. In this section, first the contexts and reasons of bilingual education are discussed. Next, a number of models of bilingual education that existed throughout the world are presented. Then, the experience of teaching and learning in a second or third language is discussed. Finally, the experience of Malaysia in regards to the teaching and learning of mathematics and science in English is presented.

The second section deals with literatures related to the teaching and learning issues in mathematics and science. Initially, research studies on classroom talk in general and discourses in mathematics and science classrooms are discussed, followed by a discussion around the importance of multimodality in mathematics and science. Second or third language learning in mathematics and science are then discussed which includes the issue of multimodal representations in second or third language mathematics and science classrooms. The final section introduces issues concerning discourse and semiotics in a broader perspective, and lastly, the perspective of this research is presented.

2.1 Second or Third Language Learning

In many parts of the world, education that involves the use of two or more languages constitutes the normal everyday experience. Many more children throughout the world have been, and continue to be, educated via a second or a later acquired language, at least for some portion of their formal education, than those who are educated exclusively via first language (Alatis & Tan, 2001, p. 332). This type of education, with varieties of models or programs, is considered as bilingual education.

Baker (2006) states that sometimes the term bilingual education is used to refer to the education of students who are already speakers of two languages, and at other times to the education of those who are studying additional languages. Garcia (2009, p. 6) contends that bilingual education is different from traditional language education programs that teach a second or a foreign language, whereas bilingual education programs teach content through an additional language other than the children's home language.

Bilingual education takes many different forms, and increasingly, in the complexity of the modern world, includes forms where two or more languages are used together in complex combinations (Garcia, 2009, p. 9). This argument is supported by Baker's (2006) definition of bilingual education which he describes as a "simplistic label for a complex phenomenon" (p. 213). He asserts that two different situations exist under the umbrella term of bilingual education: education that uses and promotes two languages and relatively monolingual education for language minority children.

Garcia (2009) states that the phenomenon of using two languages in education has long been practised, since 4,000 to 5,000 years ago in Mesopotamia until today in the 21st century, throughout the world with a variety of contexts and purposes. Since the end of World War II, political, economic, ideological and educational events have demanded a more complex use of language. Most ex-colonial countries still apply the language of the coloniser and it is not unusual for such countries to continue the colonial language as their official language, for instance in many African countries and in India (Hamers & Blanc, 1989).

Migration due to reasons such as war, consequences of revolutions, decolonisation, and the movement of labour from undeveloped regions to highly industrialised countries are among the reasons for bilingual education (Hamers & Blanc, 1989). At the same time, minority ethnic groups have become conscious of their ethnic identity and have mobilised around language as a symbol, which has contributed to the need for bilingual education. Factors such as the expansion and democratisation of education throughout the world, linguistic heterogeneity of a country or region, specific social or religious attitudes and desire to promote national identity, have encouraged the implementation of bilingual education (Garcia, 2009; Hamers & Blanc).

Ruiz (cited in Garcia, 2009) has taken a language orientation in explicating the diverse aim of bilingual education, whether language is considered as a problem, a right or a resource. From the end of World War II until the early 1970s, language was seen as a problem. In some cases especially after World War I and II, bilingual education had become an alternative for a nation whose language turns out to be the minority language, such as the Latvian language for the Latvians in the former Soviet Union. Through bilingual education, especially transitional bilingual education, children were given the opportunity to use their own language during their early grades, and move to the majority or colonial language only when they had gained their fluency in the former language.

From the 1970s to 1980s, language was perceived as a right. The role of socio-historical processes in shaping particular forms of bilingual education, and in particular the role of class, ethnicity, race, language, and gender in such shaping, was given increased attention (Skutnabb-Kangas & Phillipson, 1994; Tollefson, 1991, 2002; Wiley, 1996, 1999) as cited in Garcia (2009, p. 15). When language minorities started to claim their language rights, they started to develop bilingual education programs that supported the revitalization of their languages.

Lastly, in the third stage (mid-1980s to the present), language diversity is seen as a resource. Bilingual education has been increasingly relevant to support language differences and the dominance of languages other than English such as Chinese, Spanish and Arabic. Phenomena such as globalization, the growth of Non-Governmental Organizations and advances in technology have increased the importance of bilingual education.

The following section will review different types of bilingual education as an overview of models of bilingual education around the world.

2.1.1 Models of Bilingual Education

Many researchers have outlined the diverse models or types of programs of bilingual education that exist throughout the world. Mackey (1970) has provided an elaborate and highly detailed classification of bilingual education. He distinguished 90 different

patterns of bilingual schooling with consideration of the purpose of the language, whether as the languages of the home, the curriculum, or the community in which the school is located, and the international and regional status of the language (Baker, 2006).

Most typologies of bilingual education incorporate broad goals including contextual and structural characteristics (Baker, 2006; Baker & Prys Jones, 1998; Brisk, 2006; Fishman & Lovas, 1970; Garcia, 1997; Skutnabb-Kangas, 1981; Skutnabb-Kangas & Garcia, 1995; Spolsky, 1978). A different approach to categorizing types of bilingual education is to examine the aims of such education. Edwards (1984) states that there are two dominant models in bilingual education, which are Transitional Bilingual Education and Maintenance or Enrichment Bilingual Education. Each model promotes different goals, where the first one aims to focus on fluency in the majority language, while the second model tries to maintain students' proficiency in both minority and majority languages. Examples of Transitional Bilingual Education are to be found in United States of America (USA) and Europe, where the goal is to ensure minority children are educated in the majority language. Maintenance or Enrichment Bilingual Education are to be found in Canada and Wales, where the children are given the opportunity to use both languages at schools and become fully bilingual (Baker, 1988).

Baker (2006) in his book *Foundation of Bilingual Education and Bilingualism* portrayed ten different types of bilingual education. He divided the ten types into three groups: monolingual forms of education for bilinguals, weak forms and strong forms of bilingual education as shown in Table 2.1. Monolingual forms of education for bilinguals are programs offered for language minority children mainly aimed for assimilation and also for apartheid. Weak forms of bilingual education are types of program for both language minority and language majority children as a way for assimilation, limited enrichment and detachment, while the strong forms of bilingual education programs are offered to both language minority and language majority children with the aim to achieve bilingualism and biliteracy.