THE PROBLEM WITH WORDS IN TEACHING MATHEMATICS IN A SECOND LANGUAGE

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ABSTRACT
This paper is a report of a research on how Chinese Malaysian students who have been schooled in a tradition of technical Mathematics responded to mathematical word problems that required language comprehension and appreciation of problem contexts. The challenges faced were investigated, using action research, in a business college context where the students come from a trilingual background. It was found that rewording word problems and allowing code switching in discussions helped students' understanding, and using word problems as starting points and extensions enriched the lessons because it facilitated verbalisation and discussions. The perspective advanced in this article provides cross-cultural insights into the processes of teaching and learning in general. From this perspective, this article may offer insight for professionals in various disciplines.

INTRODUCTION

Culture is inextricably intertwined with language, and Ellerton and Clements (1991) recognized the significant role that language plays in developing one's mathematical ability. They noted that teachers sometimes mentally divorce Mathematics from language and culture, thinking that the symbolic and notational language of Mathematics is primary and hence that learning Mathematics is hardly influenced by linguistic or socio-cultural factors. In reality, Mathematics teaching and learning involve much interactive communication and dialogue, and many language-based socio-mathematical norms (Cobb and McClain, 1999). Mathematics classes are rich linguistic and social environments worthy of language-based research.

Hofmannova, Novotna, and Moschkovich (2004) advocated the need for Mathematics educators to consider socio-linguistic theories because learning Mathematics is like learning another language due to its heavy reliance on discipline-specific registers and discourses. The disciplines, here, encompass Mathematics, school Mathematics, and schooling.

The effects and interplay of language in learning Mathematics are even more significant in multilingual environments. Clarkson (2004), for example, reported case studies of teaching Mathematics in various multilingual communities, and suggested the need for more research in this area. There is not just a need for the study of language *per se*, but also the impact of socio-cultural factors, because although Mathematics appears to be culture-free and therefore the school subject least affected by linguistic and cultural considerations, the forms of Mathematics developed in different cultures are inherently and intimately interwoven with the language structures of those cultures.

Ferrari (2004) claimed that, "languages are regarded not as carriers of pre-existing meanings, but as builders of the meanings themselves" (p. 383), so the language used in communicating Mathematics is crucial in the development of mathematical thinking. He suggested that using discussions in the learning of Mathematics may help students to develop linguistic skills that are essential to understand and communicate Mathematics. "This requires a shift of emphasis from 'solutions' to verbal explanations and may involve students' and teachers' beliefs and attitudes towards Mathematics and Mathematics education" (p. 389).

Language use in Mathematics classes has a potential to be discriminatory because it influences the way mathematical skills are learned (Ellerton and Clements, 1991). This is particularly true with the learning of higher-level mathematical skills such as logical reasoning, proving, and making inferences.

Bi-cultural contexts and word problems

A study conducted by Yoong, Raman, Fatimah, Lim, and Munirah (1997) on Malaysian primary school children showed how children who have to learn Mathematics in a language that is not their mother tongue face significant difficulty in understanding and solving word problems. Bernando (1999), in his research on 283 bilingual Filipino students found that performance in word problems improved when the problems were written in the students' mother tongue. Lim (2001), who reviewed the findings of three Malaysian research studies, stressed the importance of mastering a language in order to tackle word problems in Mathematics; suggesting that one's social and cultural beliefs and values influence how one perceives and learns Mathematics and are integral to the language used in problem posing as well as solution processes.

However, some researchers have made suggestions about how to help students bridge gaps in their learning caused by the medium of instruction not being their mother tongue. Lopez-Real (1997), for example, suggested that students be encouraged to reword problems before attempting them. Bernando (1999) noted that better understanding and performance were obtained when mathematical problems were reworded in order to reduce misinterpretation errors.

Secada (1988) offered a refreshing insight when he suggested that bilingualism is an advantage for learning Mathematics. He claimed that monolingual children might be "unable to free themselves from the semantic constraints of the word problems they were encountering" due to their "lack of dual language and limited flexibility in applying strategies to new problems." Other researchers like Bain and Yu (1980) have found that bilingualism can enhance divergent thinking and problem solving skills.

Studies on students who code switched between English and Chinese (Lin, 1996) and English and Malay (Martin, 1999) have demonstrated that code switching can help students to learn meaningfully. Perhaps learning Mathematics in more than one language offers the opportunity to acquire a wider range of mathematical genres, which in turn may facilitate transfer between genres.

The Chinese Malaysian trilingual learning experience

Many Chinese Malaysian students attend Chinese-medium primary schools for 6 years, then Malay-medium secondary schools for a further 5 years, followed by English-medium post-secondary education. This results in students learning Mathematics in three different languages, and difficulties become most evident with word problems in secondary and post-secondary education.

In this paper, we report on some language aspects in a two-and-a-half year action research project where the main research question was to investigate whether Chinese Malaysian post-secondary students who study, in English, Mathematics as an enabling science were able to learn it more meaningfully using word problems. Problems were featured extensively in the curriculum instead of the usual fare of mathematical drills and abstract, "technical" questions. The focus of this paper is language issues that impacted upon this pedagogical change.

Research in this area is important because there has been an increasing shift towards problem solving and problem-based approaches in Mathematics education in many parts of the world (see for example, Pitman, 1989; NCTM, 2000). In the project reported in this paper, students were encouraged to engage in discussion, peer-group activities, and reflection – all of which are Western approaches that require verbalization and the use of language. Such practices are not commonly adopted in the hierarchical and traditional Malaysian educational environment where students are generally encouraged to be silent.

The introduction of Western teaching methods and the use of English language as the medium of instruction is increasing in South-East Asian countries, so it is important to learn more about (a) the effects of this, and (b) how the new approaches might be adapted to improve teaching processes and hence learning outcomes.

METHODOLOGY

Participants

This project was undertaken in a Malaysian private business college where 290 students enrolled in the first semester of a computing and information technology diploma course – about 40 students per semester. The majority of the students are 18 years old, and from a background of Chinese primary education and National school secondary education. Hence, they have only learnt Mathematics in Chinese and Bahasa Malaysia. For the majority of them, this was their first exposure to learning Mathematics in English. However, it should be noted that these students have been learning English as a second language throughout their years of schooling.

Assessment

Cycles of planning, then implementing a change and monitoring the outcomes, and analytical reflection leading to replanning were carried out over a period of two and a half years. Each cycle comprised 14 weeks.

Action research was an appropriate approach because the aim of the research was to explore possibilities and challenges of instituting pedagogical change. One of the authors of this paper was the teacher-researcher and the other a "critical friend" in the research process (Kemmis and McTaggart, 1988).

Data collection involved the use of open-ended questionnaires, conversational interviews and narrative observations, and students' exam papers. Reflection was undertaken through daily journal writing.

Based on the objectives of the research, various activities were carried out during the lessons. Students' feedback was obtained through the methods specified. Self-reflection was also a carried out along with discussions with a critical friend. After each cycle, changes were made, and implemented in the next cycle for further investigation.

Data analyses

Analyses of data involved grouping information gathered via these activities under topics that were generated throughout the data analysis process. Some of the analysis process was triangulated by two colleagues and a former student. In this paper, we report some aspects of what happened in relation to the language problems students faced as they tackled word problems.

RESULTS AND DISCUSSION

The problems with words

In the project, the students complained about the dependence on words in word problems, and remarked that they found such problems "difficult and confusing". An example is given below:

Ali was told by the salesman that a brand-new Kancil would cost him a total sum of RM38,800. This included a 10% sales tax and a RM300 license fee. Find the actual price of the Kancil.

One concern was the words themselves: the students did not have a good understanding in this context of "a total sum", and "actual price". Terms like "this included" added complexity to the language. They also could not translate the word problem into an equation, and this frustrated them. They made the point that Mathematics should start from equations. Herein lies cultural difference in the perception of what Mathematics involves.

When asked to attempt the question, some students would simply string together the numbers, resulting in some ridiculous answer being obtained from computation that did not reflect any understanding of the context of the question. For example:

$$\text{Answer} = \frac{10}{100}(38{,}800) + 300 = 4180$$

Cycle 1, Journal entry

Although RM4180 was far too small for the price of a car in Malaysia, the students seldom reflected upon this because they were more concerned with getting some computation done and producing a numerical answer. After having been brought up on abstract, technical Mathematics, these students had already decided that Mathematics should be notational. Their agitation and frustrations with word problems were expressed: *Student A:* Teacher, maths is about numbers and formula, not words, words, words!! Why don't you just give us the equation and we'll be able to solve it. Don't make us read words and come up with the equation ourselves. That is English, that is not maths!

Cycle 1, Questionnaire response

An analysis of the students' examination papers also revealed many students' tendency to neglect words and be preoccupied with numbers.

A tailor for a boutique is paid RM3 per hour. She starts work for 5 hours on a certain Monday and increases this duration by 20 minutes each day. Assuming she works 6 days per week,

(a) How long would she work on her fourth day at work?
(b) How much would she have earned by the end of her first week?

Cycle 3, Students' examination papers

Answer from Student B:
(a) $T_4 = 5 + (4 - 1)(20) = 65$ hours.

The above answer shows that Student B had probably not paid attention to the "20 minutes" and had assumed it to be in hours. Also, she had not reflected on the fact that the tailor could not possibly have worked for 65 hours on any one day! In an interview with her later, she laughed at her mistake and cited "not enough time" as her reason for not reflecting upon the answer.

In part (b) of the same question, Student C gave this answer:

Answer from Student C:

$$\text{(b) } S_7 = \frac{7}{2}\left[2(5) + (7-1)(\frac{1}{3})\right]$$

Student C assumed that one week had 7 days despite the fact that it was stated quite clearly in the question that the tailor only worked 6 days per week. When interviewed, Student C said she did not know what "assuming she works 6 days per week" meant and thought that it was not important.

In this particular question, there were also some students who were not sure which part required the nth term formula and which one required the sum of terms formula. They cited that the question was "not clear".

It was quite difficult to reach out to such students who had already formed an apathetic attitude towards word problems, especially when some said that their school teachers had advised them to avoid word problems in the examinations and only focus on mastering sufficient technical questions to secure the grade they aim for!

In attempts to build students' confidence and skills, problems were reworded in very simple English, using shorter sentences as suggested by Bernando (1999) and Lopez-Real (1997). Indeed, when this was done the students participated more actively. An example of rewording is given below:

At a location X in the Indian Ocean, the intensity L of light (in lumens) at a depth of x metres is given by $L = 90(0.5)^x$ while at another location Y, the equation is $L = 8(0.5)^x$.

(a) At a depth of 4.5 metres, at which location will it be brighter?
(b) A diver estimates the intensity of light to be 3.6 lumens at a certain depth at location Y. What is that depth?

Many of the students could not understand what was required in part (a) of the question. It was reworded as:

You are 4.5 metres below sea level. Where would it be brighter, at location X or at location Y?

Some students were then able to say, "We have to find the value of light (L) at X when x = 4.5 and the value of L at Y when x = 4.5". After this explanation, the algorithmic manipulation did not pose any problem at all to the students. However, they faced confusion again in part (b). Most of them assumed that they had to find the value of L again and substituted x = 3.6 to find the intensity of light at location Y. Again, rewording helped.

Cycle 2, Journal entry

Such problems were common in the first few cycles of the project, especially when a multi-variable formula was given and when the problem had different parts that asked for the value of different variables. The students had a tendency to keep looking for the same variable irrespective of the question asked. They remarked that they were used to drills where the questions were repetitive and similar algorithmic manipulation was required.

Dependence on Telltale Keywords

Some students tried to tackle word problems by looking for keywords but the teacher-researcher minimized the possibility of such guesswork by varying the words used in the problems. This inevitably coerced them to make an effort to understand the problems and not to look for telltale keywords. Willoughby (1983) wrote that this keyword method is often used by many word problem-solvers. He suggested that more real-life elements be incorporated into the question to minimize the reliance on keywords. However, I found that whenever possible, the students would still find some means of memorization instead of truly understanding a problem.

The problem below had to be thoroughly reworded.

The bank account

Compound Interest Formula

$$A = A_o\left(1+\frac{r}{k}\right)^{kt}$$

where A = amount after t years
A_o = initial deposit
r = interest rate per annum
k = number of times interest is paid in a year
t = number of years invested

Find the amount of money that should be deposited in an account paying 8% interest per year, compounded quarterly to produce a final balance of RM100,000 in 10 years.

Firstly, most students thought they had to find the value of *A* instead of A_o because that would have been more predictable and straightforward. They did not seem to bother much about the phrase "final balance" in the question – they just assumed that the *RM100,000* would be the value of A_o. Secondly, the phrase "compounded quarterly" also did not seem to mean much to them. I had to explain it to them in the following manner:

CKY : The value of k is how many times the bank pays you interest in a year. For example, if it is annual compounding, the bank pays you interest only once a year, so the value of k would be 1. If it is semi-annual?

Students : (quiet)

CKY : Semi... what does "semi" mean? As in semi-finals in a football match ... ?

Mei Ling : Half! So k is half!

CKY : You're right that semi means half, but the phrase is semi-annual, so it means interest is paid every half year, every six months. So how many times do you get the interest in one year?

Chee Heng : Half.

CKY : Not quite. They give you interest every six months, every half year, so ...

Mei Ling : Oh ... two! k is two.

CKY : Yes, very good. Now, what about "quarterly"?

Chee Heng : Three!

CKY : Not quite... quarterly means you divide the year into quarters, so, it is three months. You get interest every three months, but how many times would you get interest in a year if they give it to you every three months?

Linda : Four times?

Mei Ling : So, k is four? (and she wrote it down in her notebook)

Cycle 4, Journal entry

In the same way, the teacher-researcher explained "monthly" and "daily". The students listened but most of them were more interested in copying and memorizing the following:

Annually : k = 1 ; Semi-annually : k = 2 ;
Quarterly : k = 4 ; Monthly : k = 12 ; etc.

It appeared that memorizing the corresponding values of k was more important than understanding what periodic compounding meant or how the values of *k* could be derived from understanding the context of the problem. As a result, some students were confused again in the next lesson when a similar problem was presented.

Verbalisation and peer discussions

In the first three cycles, a lot of time was spent rewording and discussing problems in class. Upon reflection, the teacher-researcher realized that she was doing almost all the talking and explaining, and the students' understanding had hardly improved—as evidenced by their displaying little confidence in their ability to handle these problems by themselves.

Student D : Teacher, if you explain it, I understand, and then I can do it. But in the exam, I don't want to do.

Student E : Yes, I'm not sure what the question wants, it's so confusing! Sometimes it asks for this, sometimes for that. I'm not sure what it wants.

Cycle 3, Interview notes

From the fourth cycle onwards, the teacher-researcher decided to explain only one or two examples thoroughly, emphasizing the importance of attending to each of the phrases in the problem. Then the students were given time to tackle the problem in class, in small groups or pairs in order to facilitate active discussion, peer interaction, and verbalization of the students' ideas and understanding. Class observations and interviews showed that their performance and confidence improved as a result of this pedagogical change. The following interaction was recorded in the fourth cycle when students were given time to work on a problem by themselves:

Student F : Alright, the problem says: Peanuts at 70sen per kilo are mixed with walnuts at RM1.20 per kilo to obtain a mixture of 50 kilograms. If the total price is RM42.50, how much of each should be used? I don't understand the problem ...

Alan (male, national school): It sounds like the bank interest problem, but I'm not sure.

Mabel : (female, national school): You want to mix some peanuts and some walnuts so that the total is 50 kilograms ... (she draws a diagram to show Lai Fun)

Alan : Like the bank problem ... you want to put some money here and there, so that you get a certain total interest ... right? (refers to Mabel's diagram)

Lai Fun : So we solve it like the bank problem? Use unknowns? Put one unknown here, put one unknown there?

Alan : The bank problem was in Chapter 2, there we only use one unknown. This is in Chapter 3. Here we have to use two unknowns.

Mabel : Let's ask teacher if we can use one unknown for this chapter ...

Lai Fun : I think we can use two unknowns ... we just need one extra equation.
Alan : Yes, we can either use two unknowns or one unknown. It's the same. Both are the same. We will still get the same answer. You agree, Mabel?

Cycle 4, Journal entry

Zubir (1988), in her research on tertiary students, explained that a teaching and learning situation could be engineered to orientate students to learn in ways that promote learning for meaning. She also suggested that the students' conceptualisation of learning could be changed as a result of direct experience. On this note, the group work in class gave students more confidence to pursue independent work and it reduced their dependence on the teacher. They sought each other's help in understanding the problems and became more willing to struggle through on their own. Their confidence and overall competence with problems improved markedly.

Code switching

At the beginning of every cycle of the action research, the new cohort of students faced quite a culture shock having to learn Mathematics in English for the first time. I found it helpful to translate certain terminology into Malay. Among themselves, the students preferred to discuss Mathematics in the language that they were most comfortable with, that is, their own Chinese dialects. Very often, they also mixed in some Malay terminology.

Student F : In this question you must find the two *persamaan*. Then you just *selesaikan* the *persamaan serentak* and you will get the answer.

(In this question you must find the two equations. Then you just solve the simultaneous equations and you will get the answer).
Cycle 1, Journal entry

One major change made during the action research project was to allow such code switching in class in the students' discussions. This was done on the basis of advice from researchers. For example, Lin (1996), working with Hong Kong students, wrote that code switching between Chinese and English is the practical way to respond to the domination of English and to "make school learning more meaningful and accessible to the students" (p. 71).

Martin (1999) concurred in his research on Bruneian students as they code switched between Malay and English, acknowledging that code switching to Malay does more than mere annotation. His notion of accessibility resonated with the observations on the students' bilingual and multilingual discussions in this project because it was found that code switching does more than translation: it allows immediate conceptual understanding and this builds the students' confidence in proceeding with a problem. For instance, in the example above, when Student F used the term *persamaan serentak*, it immediately placed the problem in a familiar framework of the mathematical skills required.

Conceptual understanding vs. Algorithmic competence

The Sapir-Whorfian hypothesis holds that there are some languages that do not have structure through which a wide range of Western mathematical concepts are expressible (Clarkson, 1991). Certainly neither Chinese nor Malay, both well-evolved languages, suffers from this deficiency. For example, Chinese Mathematics and the Chinese language are conceptually well developed in their own right to an advanced level, so the problems faced by the students appeared to be related to how mathematical concepts are introduced to them and which aspects of Mathematics is given emphasis: conceptual understanding, application aspects or algorithmic competence. An example is given below:

There are 3 mangoes in each basket. How many mangoes will there be altogether in 6 baskets?

The students gave this example above when we discussed whether application problems were featured in their primary school Mathematics. They explained that although this example requires simple multiplication, such questions were not introduced until multiplication tables were thoroughly mastered using a sing-song method, recited repeatedly for months.

Hence in Chinese schools, the concept of multiplication is developed and understood as rote learning first, and applications come much later. This early exposure to Mathematics as rote learning has an impact on the way other mathematical concepts are learnt by the Chinese school student. It explains their preference for rote and algorithmic learning as far as Mathematics is concerned.

The Reality in Word Problems

Christiansen (1997) claimed that students may encounter serious problems of conflict between meaning as related to the everyday context within mathematical school practice and within conventions of actual real-life that require diverse solutions, lateral thinking, creative interpretations, and intuitive reasoning. This is likely to be exacerbated in cross-cultural contexts. Gerofsky (1999) similarly labelled aspects of school Mathematics as "parables" and "poor quality fiction" (pp. 38–39) because problems do not contain the ambiguities of real-life. An example is given below:

Mr Johari lives 120 km from you. Both of you leave home at 5pm and drive toward each other, you at 90 km/h and Mr Johari at 110 km/h. What time will you meet Mr Johari on the road? Assume constant speed throughout the journey.

Student G : This problem is useless, how can it be like this? What about traffic jams and traffic lights? How can anyone drive at the same speed throughout the journey?

Cycle 6, Journal entry

Since the students were often not happy with the original word problems presented to them, we worked together to insert more real-life elements into the questions. We found that the revised problems appealed particularly to the street-wise students but made Mathematics more difficult so it was once more the high achievers who could generate the correct equations to solve them. The "Mr Johari" problem was revised as follows, with input from the students:

Mr Johari lives 120 km from you. Both of you leave home at 5pm, driving toward each other, you at an average speed of 90 km/h and Mr Johari at 110 km/h. After 15 minutes of driving, you stop at a rest area for 10 minutes before continuing your journey. Mr Johari started at the same time as you but after 3 km of driving, his car was stopped by the police at a junction, and that took 5 minutes before he could resume his journey. What time will you meet Mr Johari on the road?

The students enjoyed revising the problem, inserting more "realistic features", but they also realised that realistic problems (with real-life complications) actually required more complex mathematical procedures and techniques. The students started to understand why everyday complexities were left out of school problems and they were probably better prepared for the real problems of the business world. In fact, the teacher-researcher found that by using the students' stimuli for increasing the real-life elements in the class discussions she had to widen her own knowledge of related issues. It was a refreshing challenge to keep abreast with current issues and talk to people in the business field such as insurance agents, salespeople, and shopkeepers. This was a new experience for her as most of her knowledge before this had been book knowledge.

CONCLUSION

Several conclusions can be drawn from the language aspects of this project. First, it was found that the rewording of problems and allowing code switching to Chinese and Malay facilitated better and faster conceptual understanding, and also reduced the anxiety caused by having to use a new language in its entirety. Learning became more effective because the students were able to discuss and compare mathematical concepts and methods learned in Chinese, Malay and English. This gave them a chance to look at alternative ways of perceiving and tackling a problem.

Second, having used a Western approach to learning Mathematics as opposed to a technical approach that is traditional in Chinese Mathematics, care had to be taken such that the low achievers could participate in the activities and that the Western-biased approach did not inadvertently serve to disenfranchise them. With their inherent ability for cue consciousness (Tang and Biggs, 1996), the students were quick in adapting to the needs of the curriculum while having the advantage of a more diverse cultural perspective of Mathematics after having learnt it in two (or three) different languages.

Using word problems to teach Mathematics to trilingual students was a challenge that required an understanding of and the incorporation of socio-cultural, socio-linguistic and psychological theories. This multi-disciplinary approach towards teaching and learning Mathematics is necessary and helpful for the development of more meaningful and effective learning.

At the end of the research, the teacher-researcher's decision was to use a compromised approach where she used a real-life problem as an introduction to a new mathematical concept but this was followed by straightforward problems that were not overburdened with arbitrary or irrelevant details (Toom,1999) as well as some challenging, related realistic problems. She found that using word problems as both starting points and extensions enabled the students to appreciate the usefulness of Mathematics and made learning more challenging. There was an element of intrigue and enjoyment as they strived to deduce and uncover mathematical rules on their own by observing and identifying the inherent patterns.

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