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Experiences of teaching the heat energy topic in English as a second language

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Abstract
In view of the current debate in Malaysia about the teaching of science and mathematics in English, a qualitative study was undertaken involving a purposeful sampling of three non-physics teachers to ascertain how well equipped they were with the necessary pedagogical content knowledge relating to the teaching of the topic of 'heat energy' in the second language (i.e., English) to cater to the needs of Year 10 students of diverse interests and abilities in the subject. Data were obtained using video recordings from 10 classroom observations of the teaching and learning of the following topics/concepts: (1) thermal equilibrium, (2) heat capacity, (3) specific heat capacity, (4) latent heat, (5) specific latent heat, and (6) Boyle's Law, Charles' Law and the Pressure Law. This video analysis was triangulated using data from interviews with the three teachers. The findings revealed that the teachers possessed a variety of instructional strategies to teach the concepts in English and displayed commendable ingenuity to further facilitate student understanding by explaining in the Malay language when students experienced difficulty, while at the same time insisting that students used the appropriate English terms. In addition, when not familiar with certain physics apparatus, the teachers opted for simulations of the relevant experiments. As a result, the study has introduced a new component to PCK, i.e., the role of a second language in teaching science.
Keywords: Medium of instruction; Pedagogical content knowledge; Physics teaching; Science teacher education; Science education.

Introduction
Many science education researchers consider Pedagogical Content Knowledge (PCK) as the core component of teacher knowledge (Abell, 2007) and as a conceptual tool for understanding teachers as professionals (Park & Oliver, 2008). PCK, defined as a special amalgam of teachers' knowledge of content and pedagogy (Abell, 2007; Shulman, 1987) in teaching specific topics, is the key to quality teaching and meaningful learning. Specifically, PCK is concerned with the teaching of specific topics for a specific discipline. Thus this combined knowledge of content and pedagogy forms an understanding of how the topic, problems or issues are organized and used in teaching to suit various students' interests and

abilities. Van Driel, Verloop & Wos (1998) assert that without a strong PCK science teachers would have difficulty selecting appropriate representations of subject matter.

Physics is first taught as a separate subject in Malaysian secondary schools in Years 10 and 11, to prepare students for the Malaysia Certificate of Education (MCE) Examination (Sijil Pelajaran Malaysia, SPM, in the Malay language) at the end of five years of secondary schooling. Since the early 1980s the medium of instruction of all subjects in the Malaysian education system has been the Malay language, while previously it was in English. About 20 years later, in 2003, a decision was made to revert to the teaching of all science and mathematics subjects in English beginning with lower secondary science. As by then a large proportion of teachers had already been schooled in the Malay language, special English for the Teaching of Mathematics and Science (ETeMS) programs were implemented to enable these teachers to teach in English. Hence, an additional dimension, teaching science in a second language, needs to be considered in the PCK of teachers involved in this study.

Theoretical framework

Shulman, who coined the term PCK, conceptualize it as knowledge of “the ways of representing and formulating the subject that make it comprehensible to others” and knowledge of “what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them” (Shulman, 1986, p. 9). Based on Shulman’s conception, the basic components of PCK (De Jong 2009) consists of (1) knowledge of students’ conceptions of specific topics including knowledge of students’ difficulties in understanding these topics, and (2) knowledge of instructional strategies including knowledge of representations (e.g., models, metaphors) and activities (e.g., explications, experiments) for teaching specific topics.

These core elements have been extensively investigated. De Jong (2009) has reviewed the various conceptualizations of the basic notions of PCK and found ~~out~~ that the conceptualizations of PCK are often presented as a limited number of specific core elements. For example, Grossman (1990) expanded Shulman’s definition and proposed the following four PCK elements: (1) knowledge of the purposes for teaching specific topics at different grade levels, (2) knowledge of students’ understanding, and (mis)conceptions, (3) knowledge of the curriculum and curriculum materials available for teaching specific topics, and (4) knowledge of instructional strategies and representations for teaching specific topics.
Marks (1990) also proposed four elements (partly different from the former ones) comprising of: (1) knowledge of specific topics for teaching purposes, (2) knowledge of students’ understanding of specific topics, (3) knowledge of media (e.g., textbooks, materials) for teaching specific topics, and (4) knowledge of strategies for teaching specific topics.

Tamir (1991) proposed four PCK elements that are split up into propositional knowledge (knowledge that) and procedural knowledge (knowledge how). He specified the elements for science (laboratory) lessons as follows: (1) knowledge of students: the specific common (mis)conceptions of specific topics, and, how to diagnose students’ difficulties in understanding specific topics, (2) knowledge of curricula: the pre-requisite concepts needed for understanding specific topics, and, how to design an inquiry oriented laboratory lesson, (3) knowledge of instruction (teaching and management): the usual phases of (laboratory) lessons, and, how to teach students to use laboratory instruments, and (4) knowledge of evaluations: the nature and composition of particular science assessment inventories, and how to evaluate manipulative laboratory skills.

Other science education researchers have made distinctions between more (and sometimes partly other) elements. For instance, Magnusson, Krajcik, and Borko (1999) proposed the following five elements: (1) knowledge of purposes and goals for teaching science (at a particular grade level), (2) knowledge of the science curriculum (goals and specific curricular programs), (3) knowledge of students' understanding of specific science topics, (4) knowledge of assessment in science (relevant aspects of students' learning, ways to assess these aspects), and (5) knowledge of strategies for teaching science topics (e.g., use of representations, activities).

De Jong (2009) concludes that it is clear that there is no general accepted meaning of PCK; this view highlights the need that anyone who studies and discusses PCK should be very clear about his or her conceptualization of PCK. One very ~~most~~ important component of PCK that is referred to by Shulman (1986) and is implicitly assumed in the other conceptualizations is subject matter knowledge. Thoren et al. (2008) argue that in most models for teacher knowledge, subject matter knowledge is a domain reciprocally interacting with PCK. In fact Van Driel, Verloop & Wos (1998) in a review of PCK assert that subject matter knowledge is the underlying component for the development of PCK. Subject matter knowledge is structured into substantive and syntactic areas (Grossman,1990); substantive content knowledge refers to the concepts, principles, laws and models in particular content areas of science, while syntactic content knowledge refers to the agreements, norms, paradigms and ways of establishing new knowledge that scientists hold as currently acceptable (Smith 1999). Both kinds of subject matter knowledge are needed for teachers' development of PCK.

Other than delineating the elements or components of PCK, Veal and MaKinster (1999) have presented a taxonomy of levels of specificity of PCK. At the bottom level, there is concept-PCK: knowledge of teaching and learning specific concepts (e.g. temperature). At a higher level, there is topic-PCK: knowledge of teaching and learning specific clusters of concepts (e.g. heat). At the next level, there is domain-PCK: knowledge of teaching and learning specific clusters of topics (e.g. thermodynamics.). At the highest level, there is discipline-PCK: knowledge of teaching and learning specific clusters of domains, (e.g., chemistry or physics).

In this study, ~~the~~ four main components of PCK serve as the conceptual framework: (1) knowledge of subject matter, (2) knowledge of learners, (3) knowledge of instructional strategies, and (4) the significance of second language in instruction. So far, the conceptualization of PCK does not consider the medium of instruction. All conceptualizations refer to teaching science in their mother tongue, e.g. in English. The policy of teaching science in English, whereby English is a second language to Malaysians, raises the question to what extent language has an effect on the development of PCK among Malaysian physics teachers teaching physics in English. Thus, a component of PCK that might affect the development of PCK is the 'English Proficiency' of the physics teacher (See Figure 1).

The role of second language in science education

Language is a crucial medium that a teacher requires in order to develop scientific knowledge and transmit the knowledge to learners. This is because language is used for naming new entities or to relate new findings to existing entities. Spoken language too plays an important role as it is used to debate, describe findings and to obtain speedy feedback during questioning and discussions (Lemke, 1990). In carrying out science activities, the spoken language is vital for sharing information, questioning, interpreting data and presenting arguments. The two-way process of speaking and listening is an interactive activity.

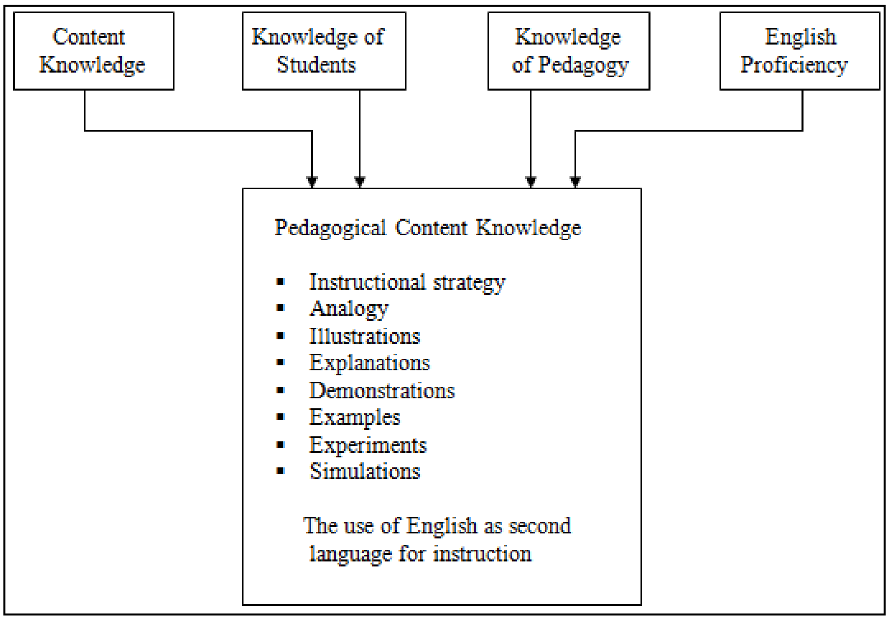

Figure 1. Conceptual framework of study. Source: Adapted from Shulman (1987) and Halim et al. (2001)

Yore (2004) argues that language is central to science teaching and learning and scientists as speakers, listeners, readers and writers use language for scientific communication. All the four skills – speaking, listening, reading and writing – are involved in teaching and learning of science. English used in the teaching of science differs from the language used in everyday oral communication (Halliday & Martin, 1993; Lemke, 1990). There are two levels of language proficiency: Basic Interpersonal Communication Skills (BICS) and Cognitive Academic Language Proficiency (CALP) (Chamot & O'Malley, 1999; Cummings, 1980), or in simpler terms, conversational language and academic language (Cassel & Johnstone, 1983). According to Wilson and McMeiman (1992), anyone learning science would have to acquire the academic language of science through oral activities, reading and writing. Windale (2001) supports this view and stresses that these techniques in active learning enable the students to achieve better understanding in science, compared to passive learning. The students are actively involved in the learning process and hence feel a sense of ownership towards the knowledge gained. These strategies involved during instruction namely, active reading, active writing, active listening and active speaking can all be practiced through simulation (Windale, 2001). It is thus evident that an effective teacher would have to be proficient in all the four skills.

Apart from the language elements referred to above, an additional dimension that needs to be considered is when the language of instruction is the second language of students and teachers. In a review of the role of second language in science teaching and learning, Kim and Wei (2007) highlight that in learning science in a second language, students need to learn two things: learning the language and learning the science. Studies on the learning of science in English in Malaysia have shown that teachers often attribute students' problems of learning science in English to their lack of proficiency in the use of the language, especially among the rural students, and not the science (Abdullah, 2009; Long et al., 2007). In particular, Kim and Wei (2007) drawing on the work of Rollnick (2000) suggest that difficulties in students' understanding of the non-technical terms and everyday words ~~that~~ lead to misunderstandings in science. Thus, teachers need to teach in the way that they develop both the acquisition of content and language. Wei and Tan (2007) suggest that teachers' communicative flexibility can achieve both aims. Communicative flexibility includes the way teachers question students in order to check for their understanding of the concepts as well as the teachers' ability to paraphrase and simplify the language suitable to the students' needs. This communication ability would to some extent depend on the teachers' English competency. In the case of Malaysia, science teachers have been teaching science in Malay since the 1980s and some of these teachers themselves have received their secondary and tertiary education in Malay. In her review of discourse based aspects of science learning, Abdullah (2009) has indicated that students' inability to understand science is due to the teachers' inability to describe the concept clearly, the inappropriate use of terminology and their lack of ability to use appropriate strategies to link the concepts. These abilities too, to some extent, would depend on the teachers' own competency in English.

Studies conducted in the Cameroons (Bunyi, 1999), Philippines (Gonzales & Sibayan, 1998) and Malaysia (Yip, Wing & Sin, 2003) have indicated that the use of the second language has a negative impact on the learning of science and mathematics. Gonzales and Sibayan (1998) reported that in the Philippines, for mathematics and science that were both taught in English, the achievement level among students in several grade levels was only about 50% and 40%, respectively. Yip, Wing and Sin (2003) conducted a study on two groups of Year 8 students, one group that studied science in the mother tongue and the other in English. The study found that the performance of students in the class that studied science in English was better only in multiple choice questions that made low cognitive demands on students, compared to the students who studied science in the mother tongue. On the contrary, for questions that assessed understanding of concepts and the application of these concepts in everyday life and questions that necessitated higher levels of cognition, the performance of students who were taught in the mother tongue was better on all the free open responses items, and the differences in mean scores are significant at the 0.001 level. Thus, the teaching of science in the second language has both negative and positive effects, depending on the expected learning outcomes as was also shown in several reviews (e.g., Long et al. 2007; Tan & Raman, 2007; Zahiah & Sallehudin, 2011).

Context of language in Malaysian science teaching

Currently in Malaysia there is an on-going debate centred round the issue of teaching mathematics and science in English. Related to this, it is pertinent to note that 30% of the teachers who attended the English for the Teaching of Mathematics and Science (ETeMS) courses were not proficient in the use of English, and their speaking and writing skills were "moderate" (Teacher Training Division, 2004). The introduction of English as the medium of instruction (for Science in 2003 and Physics in 2006) has caused considerable concern. Most of the teachers are products of an education system in which the Malay language was the medium of instruction and their "thought patterns" are shaped by the mother language (Othman & Yamat, 2003). It may be stated that practically an entire generation of students and teachers has been through an education system that had not used English as the medium of instruction. The key question is: How are teachers trained in Malay language and experienced in teaching in that language to communicate physics concepts to students proficiently and effectively in English? As teachers exert a major influence on the teaching and learning process, the quality of education depends significantly on their proficiency in explaining relevant concepts to their students.

Research questions

This study concerns how the topic 'heat energy' is presented to Malaysian Year 10 students in English. Studies have shown that there are numerous problems related to student understanding of this topic resulting in students displaying several alternative conceptions

(Duit, 2009). In the context of physics education in Malaysia, students often make mistakes in answering questions related to thermal balance, the concepts of heat and temperature, and when solving problems related to this topic (Malaysia Certificate of Education Annual Performance Report, 2003).

In addition to acquiring knowledge of students' alternative conceptions in a particular topic, teachers' PCK needs to be sufficiently developed in several other areas as explained in Figure 1. An additional component of PCK in this context is the need for teachers to be proficient in the use of a second or foreign language (i.e. English) to be able to convey the relevant heat energy concepts to students. As a result, this study was conducted in order to investigate the extent to which physics teachers were able to enable students to acquire the necessary skills/competencies relating to heat energy concepts. More specifically, the following research questions relating to teaching of the 'heat energy' topic in English as a second language were investigated in this study:

Research question 1 – What were the difficulties encountered by the teachers when teaching the concept of 'heat energy' in English?
Research question 2 – To what extent were the teachers able to overcome the problems encountered in teaching the concept of 'heat energy' in English?

Methodology

Research design

A qualitative case study research design involving three teachers was used in this study. The qualitative approach is appropriate for use when exploring and understanding phenomena about which little information is available (Gay & Airasian, 2003), while the case study design is suitable for an empirical inquiry when investigating a contemporary phenomenon in an actual context making use of multiple ways of obtaining data (Yin, 1994).

Data collection

Ten classroom observations (lasting from 35 min to 2 h) followed by interview sessions (lasting from 1h 40 min to 2 h) with the three teachers were the main source of data. The use of interviews in the triangulation process strengthened the validity of the study (Denzin & Lincoln, 1998; Gall, Gall & Borg, 2003; Yin, 1994). The lessons that were observed involved the following topics/concepts: (1) thermal equilibrium, (2) heat capacity, (3) specific heat capacity, (4) latent heat, (5) specific latent heat, (6) Boyle's Law, Charles' Law and the Pressure Law. All findings were based on interviews and classroom observations.

Data analysis

Data obtained through classroom observations and interviews was analysed in four parts: (1) academic background and teaching experience of teachers; (2) teacher's knowledge of content and learners; (3) teaching strategies used by the teachers; and (4) the teachers' use of English in presenting the concepts. To avoid bias, the first author conducted the observations with two colleagues for five of the ten observation sessions. The inter-rater reliabilities were found to be 0.82 and 0.87 with the two observers.

Participants

Two of the teachers involved in the study were from suburban schools whilst the third taught at a rural school. The three teachers who had consented to participate in the study were known to the first author but were not known to each other, and therefore were not in a position to exchange information on the study. The choice of teachers in the study was through purposeful sampling (Merriam, 1998), and involved teachers who were able to provide the required information as well as the most accurate picture of the phenomenon to be studied (Bogdan & Biklen, 2003; Gay & Airasian, 2003), i.e., teaching physics topics in a second language. The three teachers who were involved in the study were non-physics option teachers who had taught Year 10 classes for a minimum of three years. The background of the teachers varied in terms of their specialization for their bachelor degree, English proficiency at the school certificate (SPM) level and years of experience teaching the subject. Information about the three teachers (identified by pseudonyms) who participated in the study is summarised in Table 1.

Table 1. Information about the participants involved in the study (N = 3)

Demographic features	Ms Maria	Ms Rozi	Ms Lina
School type	Residential science junior college	Technical school	Semi-residential girls' school
Medium of instruction when in school	Malay language	Malay language	Malay language
SPM physics grade	C4	C4	C5
SPM English grade	C3	C6	C6
Academic qualifications & major	B.Sc. (Materials Engineering) Science University of Malaysia	B.Sc. (Mathematics) CAL State University USA	B.Sc. (Mathematics) Deakin University Australia
Teachers' college qualifications	Diploma in Education (Physics major)	Diploma in Education (Math major & Science elective)	Diploma in Education (Science & Math majors)
Experience in teaching physics	4 yr	9 yr	5 yr
Teaching experience	4 yr	11 yr	12 yr
Location of school	Suburban	Suburban	Rural
No. of physics classes taught	3	3	1

(Note: C4 – C6 are credit passes, with C4 being the highest level and C6 the lowest)

Findings

Academic background and teaching experience of teachers

Ms Maria: At the teacher training college, she took courses in teaching and learning strategies as well as learning theories and specialized in the planning and teaching of the physics curriculum. The macro and micro teaching skills that she acquired at college were specially tailored for teaching physics at Year 10 and 11 levels. Her content knowledge was obtained through her secondary schooling and pre-university physics texts. Maria has improved her knowledge of instructional techniques through the courses, both at school level and those organized by the district education office, and through discussions with more experienced colleagues. Maria has also been an examiner for SPM Physics for two years, and this has been an asset as she is now familiar with the correct techniques for answering the structured and essay-type questions. She was able to speak spontaneously in English when answering questions related to the subject matter. Occasionally, however, her usage of terminology was not accurate. Her interaction with the English teachers is limited as she spends most of her free time preparing teaching materials. Maria teaches three physics classes: one class made up of students who scored grades A and B for mathematics and science in the Lower Secondary Assessment (PMR in Malay) examination the previous year, Form 4B (students with grades B and C) and Form 4C (students with grade C).

Ms Rozi: Rozi attended seminars and workshops that were conducted by the Ministry of Education specialists on answering physics exam questions from previous MCE/SPM examinations at her own expense before being appointed as examiner for the subject. Through her teacher training, she developed her subject knowledge through self-study. She would discuss physics subject matter with those who had specialized in the teaching of that subject at district level meetings for physics teachers. Her knowledge of teaching techniques pertaining to specific topics improved through discussions with experienced teachers whose students were of similar ability. As she doesn't use English in her daily interactions, her language skills could only be gauged during classroom observations. Rozi teaches three physics classes, and the students are placed in the different classes based on their mathematics and science results in the PMR examination of the previous year.

Ms Lina: Lina is an experienced mathematics teacher who started teaching physics five years ago on the request of the school administration due to her good English proficiency. As a teacher with positive attributes, coupled with the desire to explore new experiences, she took on the task. After joining the teaching profession, Lina developed her physics subject knowledge through self- study (using reference materials and computer software). As for exposure to physics teaching techniques, this was acquired through discussions with teachers who attended the ETeMS course for which she later became facilitator. She has a collection of instructional software for the teaching of science and physics in English, both for her own use and others who attended the ETeMS courses. She teaches in a rural school that does not have a large enrolment, and her students are not high achievers in the PMR as those from relatively affluent families have moved to residential schools. Since the best students have left the school for residential colleges, Lina has only one mixed ability group with students whose performance in mathematics and science in the PMR ranged from A to C.

Teacher's knowledge of content and learners

Subject matter knowledge. In the context of this study, content knowledge refers to the teachers' understanding of concepts, ability to relate these concepts to natural phenomena or everyday life, the application of the concepts to calculations, description of structure, and the knowledge for setting up the experiment(s) and being able to describe how the experiment is to be conducted. Additionally, content knowledge would also incorporate knowledge of the learning outcomes to be achieved as well as the link between the concept (heat energy, in this study) to other concepts both in physics and outside the discipline. All three teachers displayed sufficient understanding of the concepts and the necessary requirements of the syllabus during classroom observations.

Knowledge of learners. This attribute involves ascertaining the learners' pre-requisite knowledge necessary to facilitate the acquisition of new knowledge or concepts, known learners' misconceptions, learners' difficulties pertaining to English proficiency and potential problems in learners' understanding of the concept of heat energy. The teacher needs to know the learners' existing knowledge and past experiences so that the presentation of subject matter is adapted or tailored to the learners' achievement level. Rozi resolved this problem in different ways with her class of high-achieving students and another of low achievers. With the former class, Rozi used the Socratic questioning strategy extensively and the content covered was extensive, but with the latter class she opted largely for the expository method. In the case of Lina, her students had varied proficiency levels of English. The students were from a rural school. Thus, her strategy was to simplify the use of English language (namely the use of DARTS) so that the students were able to learn the content in English as shown in this quote (i.e. relating to the fact that students had difficulty in answering open-ended questions):

> *I think some of them cannot construct sentences in English. The open-ended past years SPM questions were too difficult for them to answer but they were willing to do the cloze passages, just filling in the blanks.*

Maria, on the other hand despite being aware of her students' difficulty failed to do any adaptation or tailoring of her teaching. She realized that low-achieving students had difficulties in solving physics problems compared to the more able students. She did not guide the weaker students step by step to the end in solving a physics problem.

Teaching strategies used by the teachers

The teachers used a repertoire of teaching strategies to present a particular concept on 'heat energy'. The instructional techniques included illustrations, explanations, demonstrations, examples, experiments and simulations. Table 2 summarizes the teaching strategies that were used by the three teachers during their instruction on the 'heat energy' topic.

Table 2. Frequency of use of instructional strategies in each topic

Topics	Participant (no. of lessons)	Illustrations	Explanations	Demonstrations	Examples	Experiments	Simulations (Roleplay)
Thermal equilibrium	Maria (1)	2	3	-	1	-	-
	Rozi (1)	3	6	1	2	-	-
	Lina (2)	2	5	-	3	-	-
Specific heat capacity	Maria (1)	-	5	-	4	1	-
	Rozi (1)	-	3	-	2	1	-
	Lina (2)	-	6	-	5	1	-
Specific latent heat	Maria (1)	2	5	-	3	-	-
	Rozi (1)	5	8	-	2	-	1
	Lina (2)	2	4	-	2	-	-
Gas laws	Maria (1)	2	8	-	3	3	-
	Rozi (3)	6	10	-	3	3	-
	Lina (2)	5	6	-	3	3	-

The use of experiments, for example, provided opportunities for the students to discuss with each other and to explain to their peers in the Malay language when they faced problems associated with the experiment. Experiments were employed by all three teachers to facilitate understanding of the concepts of specific heat capacity and gas laws. Maria observed that students were able to understand a concept faster if they have the experience of planning, executing and observing the results of experiments related to the concept. Experience alone, however, does not it itself result in understanding unless the learner processes information and reflects deeply on what he has experienced (Martin, 1997). By processing information, a learner better understands a concept and hence is more likely to remember the concept. Rozi said that experiments challenged a learner to reconstruct ideas after observing the results of an experiment. Maria's view was that experiments helped learners acquire scientific skills, especially science process and manipulative skills. Maria conducted an experiment to enable her students to deduce the effects of changing one variable by keeping another constant. The experiment involved studying the relationship between changes in temperature when the same amount of heat energy was used to heat up different masses of water (see Figure 2).

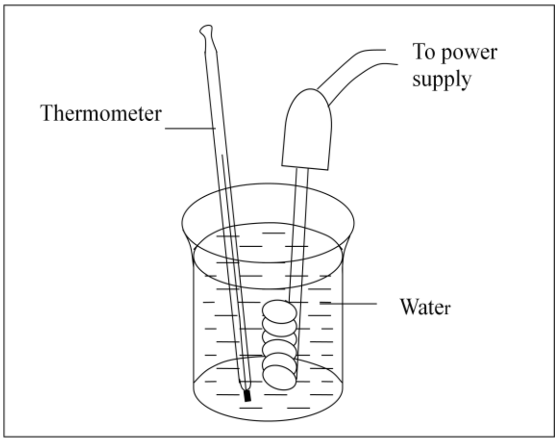

Figure 2. Experiment to study the relationship between temperature and mass of water heated using the same amount of heat energy.

Time constraints made it rather difficult for the teachers to resort to extensive laboratory activities but they used ICT activities as an alternative.

Teachers' use of English in presenting the concepts

Although there has been a change in the medium of instruction – from the Malay Language to English – the teachers remarked that the way they taught the subject remained unchanged, that is they continued to employ the same instructional strategies. Rozi's comment was:

> *We shouldn't cut down on our explanations just because our proficiency in the language is not up to the mark. So immaterial of whether I'm good or not, I just do it. Whether I use Malay or English or a mixture of both languages, I do so if it is important.*

The teachers were of the opinion that how a concept is represented is not influenced by the language. The teachers' responses demonstrated that their language competency did not impede their acquisition of content or PCK development, thus implying that language competency had no influence. The teachers who were involved in the study started teaching Physics in 2005 when the medium of instruction was the Malay Language. Their PCK at that point was formed in the Malay Language. English played no part in their PCK development as the reading materials they had access to, their subject matter knowledge and their training were in the Malay Language. The teachers believed that the change in the language of instruction had no bearing on the subject content.

In teaching the topic of heat energy, the teachers applied the PCK they had developed when they taught the subject in the Malay Language though the content had to be translated into English. The language change only impacted the way they transmitted (both orally and in writing) the subject matter knowledge to the learners. Maria admitted that due to her language limitations her explanations were not very effective. Her limited vocabulary both in terms of suitability and accuracy, impinged on her ability to construct complete sentences to convey what she intended to convey. The following comments reflect Maria's the dissatisfaction:

> *My presentation is kind of choppy, not fluent. I have to think of the suitable word when I explain …. I have the knowledge but I have difficulties expressing it. That makes me unhappy.*

All three teachers used both English and Malay depending on the learners' needs. Sometimes the concept was explained in English followed by a repetition in Malay. The other practice was to use a mixture of the two languages. One of the teachers, Ms Lina, introduced the physics terminology in English before starting off the session, whereas the other two introduced the terms during the lesson as the need arose. There was a deliberate attempt on the part of the teachers to repeatedly use the terms to facilitate student retention of the understanding of the terms. The focus was on ensuring that the teaching outcomes were achieved, thus the teachers ignored language errors unless it led to misconceptions amongst students.

However, they differed in opinions if the error does not affect the subject matter. Lina stated that science was taught in the medium of English to improve students' proficiency in the language. It was therefore her responsibility as a science teacher to correct the errors. Maria and Rozi did not correct the errors. They believed such action would discourage the students, particularly the weaker ones, from asking any questions in future because the mistake could bring laughter to their peers. They felt that teachers should encourage student interaction in the classroom and so they focused more on the physics content, leaving the grammatical corrections to the language teachers.

The subject knowledge transmitted was both in oral and written form so that students could hear the word articulated as well as take note of the spelling of a word in the written form. The listing of key words on the white board or projecting on the screen was to make it possible for students to note the spelling. This was deemed necessary as these are not words used in everyday life.

Discussion and Conclusion

In response to Research question 1 (What were the difficulties encountered by the teachers when teaching the concept of 'heat energy' in English?), the teachers' own limited proficiency in English as well as that of the students posed major problems to the teachers. Teachers with limited proficiency in English could not conduct a lesson smoothly at times because of unexpected questions raised by students. However, the teachers went to great lengths to memorize the concepts in English to ensure smooth delivery of the content. In addition, students' errors of language and content were further problems the teachers had to address. When students were unable to understand, the information was translated into Malay but teachers insisted on using the English terms (e.g., specific latent heat of fusion, specific heat capacity, etc.) during their explanations. Notes were given to the students in English, to ensure that students read the notes and answered the examination in English. In this case study, teachers as curriculum implementers appear to perform their tasks despite the difficulties they face. As highlighted by Jenkins (2000), teachers are obliged to follow and execute the curriculum as stipulated. As a result if teachers find that the curriculum is oriented towards teaching science and mathematics in English then teachers will try to teach the concepts in English, as shown in this case study, despite knowing the difficulties faced by the students understanding the material in English.

This case study indicates that there is a tension between implementing the policy of teaching of science and mathematics as directed by the Ministry of Education against implementing the policy in view of helping students to learn meaningfully.

In response to Research question 2 (To what extent were the teachers able to overcome the problems encountered in teaching the concept of 'heat energy' in English?), the teachers addressed the problem of their limited language proficiency by spending more time preparing their lessons. They have demonstrated their willingness and determination to conduct the lessons to the best of their ability.

The use of several instructional strategies (e.g., illustrations, explanations, demonstrations, examples, experimenting, simulations, demonstrations and explanations) provided more opportunities for students to be actively engaged in their learning. The teachers further facilitated understanding by explaining in Malay whenever students experienced difficulty with the English explanations. The teachers constantly repeated definitions and explanations so that the language issue did not pose a barrier to students' understanding of the heat energy concepts.

The integration of subject knowledge, pedagogical knowledge, knowledge about the learners and the relevance of a second language in science teaching developed the teachers' PCK. The PCK thus developed made it possible for the teachers to adapt the subject knowledge and transmit it in a way that was easily comprehended by the learners. Language competence was not a deciding factor in the choice of teaching strategies but affected teaching quality in that the information was not as detailed as expected, and the teachers could not spontaneously provide or elaborate on examples. In this respect the use of English had a negative impact on the quality of the explanations given. The descriptions and reasoning became less effective as the teachers lacked the requisite language skills to transfer their knowledge, and for the same reason details were also sacrificed. Despite this shortcoming, the continued use of Malay together with English in instruction clearly helped promote learners understanding of the concepts that were taught.

The findings of this study suggest several implications for practice. First, non-physics major teachers need to have a solid grounding of the concepts involved by improving their subject knowledge through reading relevant materials as well as by communicating with other physics teachers. Second, teachers ought to be given more opportunities to attend courses or workshops that focus on specific skills related to the inquiry approach to teaching science that involves hands-on activities, scientific skills and laboratory management. The pedagogical knowledge, especially subject-specific pedagogy will enable the teacher to plan and execute their lessons more effectively with greater confidence.

Third, trained as well as untrained science teachers are posted to schools by the Ministry of Education; they are not directly hired by headmasters. Due to shortage of teachers in the country, the teachers assigned to schools may not be based on the requirements to teach particular subjects. So, if headmasters have no option but to assign teachers who are non-physics majors to teach the subject, then the more experienced science teachers rather than novices need to be considered. Fourth, in view of the time constraints experienced by the three teachers to conduct hands-on activities like experiments and demonstrations, school administrators should consider allocating at least two double periods (of 70 or 80 minutes duration each) for science subjects.

The findings of this study also suggest that there is urgent need for further research to identify successful instructional strategies that could be used for other physics topics/concepts in the curriculum and for preparing a bilingual teachers' guide in English and Malay that could be used by both physics majors and non-majors who are not fluent with the English language. In addition, teacher training programs should place greater emphasis on better equipping preservice teachers to become more confident and proficient to teach physics (or for that matter, any science subject) in English. In conclusion, it is apparent from this study that the efficacy of the three teachers was restricted by the lack of support from relevant sources as mentioned above; merely providing teachers with a one-off inservice course or just covering the necessary content in English during preservice training is not going to produce the desired results. There is need for continued pedagogical support for teachers until they are confident enough to manage on their own.

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