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Issues and techniques in translating scientific terms from English to Khmer for a university-level text in Cambodia

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In spite of the numerous calls from education and language specialists, many countries still use the languages of wider communication instead of their native languages (Clayton, 1998a; Clayton, 2008; Phillipson, 2001). As a result, students are often required to learn subject material in the language of a former power; a language in which they may not be proficient. Despite countries' best efforts to teach in native languages, this becomes more challenging in developing and postcolonial nations where no text may be available in the language of the learners (Apple, 1992). In this paper, we present a case study of a translation process designed to create an L1 science text for Cambodian university students that attended to cultural, linguistic, and social components of language.

Cambodia offers an interesting case study for the documentation of text translation because of the numerous transitions in its history. Before the French arrived, education in Cambodia was limited to boys and was carried out by Buddhist monks in wats (Ablin, 1991; Quinlan, 1992; Torhorst, 1966). The curriculum generally consisted of reading and writing in Khmer, learning principles of Buddhism, and basic mathematics. Although literacy was encouraged, this education served a broader purpose. Beyond curricular goals, wat education was intended to support social solidarity by encouraging traditional values (Quinlan, 1992). Education during this pre-colonial era was a Cambodian endeavour and intended to serve and enhance Cambodian goals (Clayton, 1995; Clayton, 1998b; Quinlan, 1992; Torhorst, 1966).

During the French colonial period (1863-1953), French served as the language of international communication (Clayton, 1995). In 1975 to 1979, when the Khmer Rouge and its leader Pol Pot attempted to create a primitive form of Marxist communism, they caused severe destruction to Cambodia (Savin et al., 1996). Although numbers are extremely hard to calculate, the Khmer Rouge executed at least 20,000 people. Estimates of the total number of deaths resulting from Khmer Rouge policies, including disease and starvation; range from 1.4 to 2.2 million out of a population of around seven million (Jackson, 1989). During this time, the

Khmer Rouge also prohibited the use of all Western languages in order to achieve autonomy from international political and economic structures, which were seen as manipulative (Clayton, 1998a). After the defeat of the Khmer Rouge, it was estimated that there were “no more than 300 persons who had post-secondary education remaining in Cambodia; and most of those left the country as soon as they could” (Sloper, 1999 p. 7). The Royal University of Phnom Penh (RUPP) was in ruins, having been looted and then abandoned for more than four years (Howes & Ford, *in press*).

Then during the Vietnamese occupation (1979-1989), Western languages were still controlled in order to limit participation in international relations as a part of Vietnam’s commitment to the USSR’s communist system. In 1989, Vietnam withdrew from Cambodia and the country underwent three simultaneous transitions. Politically, the single-party communist regime transitioned to multiple parties with democratic principles. Economically, Cambodia shifted to free market economy principles. Developmentally, a national emergency initiative encouraged international aid efforts (Clayton, 2002). These three transitions - politically, economically, and developmentally - increased English usage in Cambodia. Although the 1989 decision that removed the communist ban on Western languages allowed Cambodians to choose languages with freedom, the majority of Cambodians chose English in order to compete in a global market (Cambodian Country Report, 2007). In junior high schools, the government generally provides English lessons, but higher education students have to pay for such language lessons themselves (Clayton, 2002). Therefore, although the students desire to learn English, this choice is not available to those who cannot afford it.

Despite this history, higher education is now widely available in Cambodia, and through the medium of Khmer, the national language (Howes and Ford, *in press*). RUPP, which is Cambodia’s oldest and largest university, has 10,000 students and 300 faculty members. Even with instruction being conducted in Khmer, however, the university still faces another difficulty: Cambodian students are reliant on English textbooks since texts in Khmer, particularly on technical subjects, are not available. Countless Khmer science texts were either lost or destroyed

during the Khmer Rouge regime. This, combined with the loss of so many educated Cambodians, in particular scientists and RUPP faculty members, makes the educational situation in the country even more challenging, as many Cambodian scientific words are simply unknown or lost, or more likely never existed (RUPP Handbook, 2007-2011).

In spite of these challenges, the university is engaged in translating texts from English into Khmer so that their students will have an L1 resource. In this paper, we analyse the work of a particular university teaching team at RUPP, comprised of native speakers and science professors, who translated a text to Khmer. It is our hope that, through this case study, educators in other postcolonial contexts may become aware of some of the key issues involved in producing high quality translations of scientific texts, and that they may be prompted to consider embarking on similar enterprises in their own national languages.

Relevant Research on Translation Studies

When educators teach curricula through the students' home language, it provides a congruent relationship between language and knowledge (Gallas, 1995; Hogan & Corey, 2001; Lee & Fradd, 1998; Lukyx et al., 2007). One of the keys to this congruence is the availability of texts in the learners' home language. Science teachers face another challenge when teaching in diverse language classrooms: the complexity of scientific discourse itself. In effect, they are introducing yet another language in their classroom, the language of science. As Lemke (1990) pointed out, the language of science is composed of a specialized system of semantic constructions (i.e., "thematic patterns") whose employment requires mastery over a particular set of language-dependent concepts. These are often not readily made available to students, making science learning difficult as they grapple with unfamiliar ways of talking, reading, and writing. In general, school science requires students to integrate the practices of prediction, observation, analysis and presentation with science reading, writing, and language use (Lee & Fradd, 1998). This ability to 'talk science' has served as a gatekeeper to the sciences, preventing many students from having access to academic success (Lemke, 1990). Thus, the added complexity of scientific-discourse translation presents a unique challenge for science teachers.

As teachers begin to translate texts or science words, there are often many words and terms that are very difficult to translate and often unintended meanings emerge during translation. However, there has been little research on this complex process. Most translation research is focused on assessment and curricula. At an international level, educational researchers have sought to create multilingual written instruments capable of producing global measures of student learning and achievement that are both reliable and valid (Brislin, 1988; Ercikan, 1998a, 1998b, 2008; Fawcett, 2003; Luykx, et al., 2007; Zumbo, 2003). For instance, the International Association for the Evaluation of Educational Achievement (IEA, the French acronym) has conducted international assessments of mathematics and science over four decades. Another good example is the Trends in International Mathematics and Science Study (TIMSS), which were administered in over 40 countries in 2007, requiring the translation and adaptation of the Grade Four and Grade Eight assessments in dozens of languages. Also, translation has been an integral part of the Program for International Student Assessment (PISA).

Thus, much attention in translation research is focused on test adaptation and data collection tools. In a study on the effect of translation on the equivalence and comparability of international assessments, Ercikan (1998b) described how the word “cool” was changed to “refresh” during the translation from English to French of a question about body temperature. As a result, only 10% of French students answered this question correctly, compared to 44% of English-speaking students, suggesting that students who took the original English version of the test had an advantage over the French-speaking group. In addition, Luykx et al. (2007) focused on how language influenced children’s responses to science assessments. By employing qualitative discourse analysis of the students’ written responses to test items, they concluded that English-only assessments are unlikely to accurately measure the scientific knowledge of culturally and linguistically diverse students.

A number of linguists explain the ways in which translators can increase the validity of the translation process and how they can employ these tools. For example, Beaton et al. (2000)

describe five stages they believe are necessary in order to accurately translate documents. These stages include: (1) Translation by two translators, (2) Synthesis of the two translations and resolution of any discrepancies, (3) Back translation (translating the target text back into the source-text language to check for any errors in translation), (4) Expert-committee review by the translators and stakeholders, and (5) Pretesting by the audience to check for the validity of items. In their employment of these stages, they found that many errors in translation were resolved during the process itself, so that equivalence in the meaning of the texts was achieved. Specifically, they found a need for a team of translators to work together instead of having just one translator working on the text.

Additionally, Ni (2009) described translation as a multidisciplinary and interdisciplinary endeavour and remarked that using translators from different fields helps to achieve equivalence between source and target texts. She referred to Vinay and Darbelnet's (1996) theory to describe the small 'shifts' in meaning that can occur when words are translated from source texts to translated texts (p. 78). She defined the use of the following techniques in the translation of English to Chinese words: *borrowing* (the source language word is transferred directly to the target language), *literal translation* (word-for-word translation), *transposition* (translating the words while paying attention to linguistic differences such as placement of adjectives before or after nouns), *modulation* (a technique often adopted when literal or transposition translation results in a utterance that, though grammatically correct, appears abnormal or awkward), and *equivalence* (a technique similar to modulation often used in idioms, proverbs, and phrases). Ni argued that in order to accurately translate documents, all these techniques must be used. Furthermore, translation through modulation and equivalence requires great attention to cultural, lexical, grammatical, and syntactic aspects of the text. However, she observed that even with attention to the subtle meaning shifts occurring during the translation process, translation errors can still occur.

Similarly, Campos, Buenfil, and Piño (2008) examined the main problems faced by translators from English to Spanish and outlined the same translation techniques as Beaton et al.

(2000). The researchers asked bilingual students to translate words from English to Spanish and to discuss the challenges they experienced during the process. Most of the participants were bilingual graduate students in the fields of English or Spanish literature. Translation problems were divided into linguistic problems and cultural problems: the linguistic ones included grammatical differences, lexical ambiguity, and meaning ambiguity; the cultural problems related to different situational features. The findings point to the paramount importance—when translating English to Spanish—of including several translation techniques (borrowing, literal translation, transposition, modulation and equivalence). They described the particular need for equivalence and modulation. Equivalence, as a strategy or technique, comes into play when the translation unit is an idiomatic expression, a cliché, slang, a proverb or saying, or contains a specific cultural reference, and it becomes necessary as a result for the translator to look for some equivalent concept in the target culture. Additionally, modulation as a translation technique involves changing the semantics and point of view of the source text. Literary devices, such as simile and metaphor, are best translated by means of a modulation technique.

Reiss and Vermeer (1984) propose a model for improving translation accuracy and argue that educators should be examining the level of text difficulty. They posited that text difficulty (and ultimately translation difficulty) depends on five aspects: the subject matter, the register, the type of language used, the pragmatics of the reader, and the historical-cultural context. Campbell and Hale (2002) examined how text difficulty can affect translation. They discovered that text difficulty played a significant role in Spanish and Arabic translators' ability to translate texts. They called for further examination of this issue and further investigation into the difficulties presented by the translation of certain words.

Even with studies calling for greater attention to the translation of curricula, texts and assessment, and identifying the best ways to do this work; there still remains a paucity of research on the translation of science texts showing specifically how teachers can create good L1 texts for their students. Only when we have such research can we extrapolate the findings for use in our

own classrooms and help educators in developing countries who are attempting to create L1 texts for their own students. Currently, little is known about how teachers deal not only with the complexity of translating text generally, but in particular with translating science text, which is arguably another language altogether (Lemke, 1990). The present study focuses on this issue by exploring the challenges and successes a university teaching team experienced when translating a science text from English to Khmer. It addresses in particular the question of how scientific words that cannot be easily translated from English to Khmer should be dealt with.

Theoretical Framework

We framed our study using an integrated approach, incorporating theories from linguistic and translation. We viewed these as two interdependent fields: linguistics as the systematic, theory-oriented study of how language works in particular social contexts, and translation as a practical or applied multilingual activity (Fawcett, 2003). The theoretical model we adopted to examine texts in different languages is functionally oriented, emphasizing that translation involves more than the simple, unproblematic transposition of the literal meaning or message of a text into a target language. Attention must also be given to the text's social functions. Translators who adopt a functionally-oriented approach attend to both of these textual dimensions and seek to produce equivalence of meanings at both semantic and pragmatic levels (House, 1997). From this theoretical perspective, texts are viewed not simply as a random collection of words but as a cohesive stretch of discourse with socially constructed meanings. As we compare the English and Khmer versions of an instructional text, we are therefore attentive to the functionally-oriented textual dimension and to how its translation can potentially affect how students understand science and relate it to their lives.

Another important aspect of our theoretical approach was paying careful attention to the purpose of the text. As with all texts, scientific texts serve a specific purpose. In the case of the text '*Fundamentals of Geomorphology*' which is central to the present study, the purpose is to teach undergraduate students the basics of this field. Therefore, the function of the text is to

inform since it is written in an expository and detached style. In order to establish the purpose of a text, a systematic analysis of its linguistic features in relation to the context of its use was needed. This analysis involved considering three contextual dimensions: field, tenor, and mode (Halliday, 1975). Tenor and mode are related to the nature of the social activity that occurs while the text is read (the role of language and participants' roles and relationships respectively). Because we are presently only addressing the translation process of this text, tenor and mode will not be examined during this study. However, we attended to the dimension of *field*, the nature of the social activity that occurs while a text is used or the language speaks to the culture in which a text appears (Halliday, 1975). The field component was central to our analysis of how scientific words are introduced in instructional texts (e.g. in-text word pairs, picture captions, glossary, etc.).

A final component of our theoretical approach is the incorporation of translation theory. We use the translation techniques developed by Vinay and Darbelnet (1996) to describe the process of translating the text. Our perspective was that while these techniques do not guarantee the quality of translated instructional texts, they do provide a systematic method or framework for examining the translation process and for identifying strategies that lead to the production of a target text that is coherent with the reader's perspective as well as semantically and pragmatically coherent with its source.

Methodology

We adopted a case study approach to the exploration of the translation of the earlier mentioned geomorphology text from English to Khmer by a university science teaching team. This approach combined both qualitative and quantitative data collection and analysis.

The Project Team

The project team, not all of whom were directly involved in the actual translation process, consisted of the following people: (1) Author One, a science educator from the US with moderate Khmer language skills (basic reading and speaking) and previous experience as a science teacher in Cambodia. (2) Author Two, a science and language educator from Brazil who is currently teaching in the US and researches curriculum translation. (3) Author Three, a British volunteer

lecturer seconded to RUPP from OMF International (formerly Overseas Missionary Fellowship) who is fluent in both Khmer and English. (4) Author Four, a US science educator who specializes in gender and diversity issues in urban areas. (5) Mr. Noun Horn, who is a native Cambodian geography professor at RUPP and fluent in Khmer and English.

Two final-year geography undergraduate students helped to check the translation. Others who contributed to the project included senior faculty at RUPP who approved publication of the translated textbook; a translation specialist who is a native Cambodian fluent in both Khmer and English and who has worked in the English language department in the Institute of Foreign Language at RUPP for nine years; an independent Cambodian consultant who is fluent in both English and Khmer but has no current associations with the university; and finally a Cambodian student who is currently pursuing his doctoral degree in the US in Language Education.

Author Three and Mr. Horn were the textbook translators. The geography students and senior RUPP faculty who served as consultants during the translation process assisted them. Subsequent to the translation phase, Author One and the translation specialist conducted the back-translation. Authors Two and Four, who were not involved with the translation process, came together with Authors One and Three to collaboratively research the translated textbook.

The Khmer language

The official language of Cambodia is Khmer, a Sanskrit-based language that contains 33 consonants, and 20 regular and 15 independent vowels. Khmer is a grammatically simple language without verb tenses or plural forms of nouns. However, the vocabulary for expressing relationships, status, and respect is far more extensive than that of English. For example, the personal pronoun “you” in English translates into 14 different Khmer words depending upon the age, sex, and status of the speakers, including specialized forms for “you” in the case of a Buddhist monk or a member of the Royal family (Howes & Ford, *in press*). These differences in the linguistic expression of politeness cannot be translated into English and illustrate one of many challenges these teachers faced.

The text

In order to strengthen capacity in RUPP's Department of Geography and Land Management, staff developed '*Fundamentals of Geomorphology*', the first geomorphology textbook in Khmer.

Geomorphology is the science of Earth surface landforms and landscapes, their formation, morphology, processes, evolution, and interaction with human systems. National faculty identified the need for this project when they noticed the lack of written teaching resources in Khmer.

Author Three and Mr. Noun Horn developed the text together, and implemented it in the 'Dynamic Geomorphology' module for second year undergraduates. Much of the Khmer text was based on Author Three's lecture notes, tailored for a Cambodian audience while retaining a global perspective (i.e. discussion of the Tsunami in South East Asia in 2005 and global warming issues).

The present analysis of this text was confined to Chapter 5, 'The Formation and Deformation of Rock', which consisted of 32 pages out of a total of 155. The overall purpose of this chapter was to describe the processes of formation and deformation of different rock types. We used this chapter of the textbook at Author Three's request because it was the most complete in terms of translation at the time of this study.

The Translation Process

As shown in Figure 1 below, the preparation and translation process involved 7 steps. (1) Initial drafting of the text (in English) by Author Three; (2) translation of these notes from English to Khmer by two final-year geography undergraduates; (3) back-translation and correction of the meaning by Author Three; (4) further editing by the two translators to correct linguistic errors and inconsistencies; (5) classroom testing of the translated material in lectures given by Author Three and Mr. Horn; (6) revising and correcting remaining errors identified during the teaching process; and (7) final checking and approval of the text by senior faculty, prior to internal publication and printing.

Figure 1. Textbook translation process.

Sources for Translation Analysis

The primary sources for this study include the original English version of the text; the Khmer translated version of the text, the back-translated version of the text, and the English-Khmer word pairs (described more fully below).

Source Text: The original English version of the text, which was used as a guide for the instructors who translated the text.

Target Text: The translated Khmer version. Author Three primarily translated the Khmer version of the text, but frequently consulted Mr. Horn for assistance particularly with scientific terms.

Back-translated Version: Author One worked collaboratively with the Cambodian native Khmer/English translation specialist to back translate the text. Back translation involves translation from the target language, Khmer, back to the source language, English. The back translation was a word-for-word translation, which included back translation of the text and a comparison of the second adapted versions. Back-translations are temporary texts in the sense that they are not used by anyone for any purpose other than as a temporary tool employed in the translation process to check the quality of a translation. Back translating from Khmer to English was verbatim, meaning no adjustments or modifications to improve coherence were made. For example, because of how the Khmer language places the modifier after the noun, a literal

translation of “coat blue” remains as such even though during translation the modifiers would normally be switched to read “blue coat” in order to provide a more coherent reading. An independent Cambodian consultant then reviewed the back-translated text and found several errors (misspellings and wrong word order). The two versions of the text were then compared for similarities, differences, and translation techniques.

Word Pairs

During the translation process, it became apparent that many scientific words were not known in the Khmer language. Wherever possible, the team sought to use existing Khmer words rather than to create new terms. However, the translation team paired many of the scientific words with Khmer descriptive words side-by-side if they were unsure of the translation. We call these pairings, “word pairs” from this point forward in the text. A word pair includes a foreign word form and its translated meaning (Nation, 1982). Here in this study, a word pair consists of a scientific word in English followed by the Khmer translation. The university teaching team chose to leave English and Khmer words together, thus creating a word pair, when they could not ensure the accuracy of the translation. During our translation analysis, the Authors compared the English, Khmer and back-translated words and noted the process used during the translation. Similar to the creation of the back translation version, these were thoroughly reviewed by Authors Three and the Cambodian translation specialist.

Translation Analysis

Our analysis centred on the source, target, and back-translated texts. The analysis served four purposes: (1) to produce a frequency table of scientific words, (2) to provide a context for how the word was used in the text, (3) to provide a comparison of English and Khmer meanings of the scientific words, and (4) to provide us with an account of the translation processes and translation techniques themselves. We focused our analysis on the 102 scientific Khmer-English word pairs.

Findings

Translation techniques

Our analysis revealed five techniques used in the translation. These were previously described by Fawcett (2003) and Vinay & Darbelnet (1996) and were briefly mentioned earlier:

(1) Borrowing: the process of taking the source word (un-translated) into the target language because the source language term cannot be translated into the target language, or the source language term is more widely accepted. An example of the latter would be where Indian IT representatives talk of the “internet”, even though this word can be translated.

(2) Transposition: the process of translating words but rearranging them to make the meaning clearer. This happens in many translations into English, because the modifier is introduced before the noun: for example, the English words “lava rock” being rearranged when translated into some other languages so that the modifier follows the noun (i.e. equivalent to “rock lava”).

(3) Modulation: the process of using a similar phrase, but different words, to convey meaning. For example, the words “the force of the earthquake moved it” would be translated into some languages in a form roughly equivalent to “the earthquake force it moved”. Modulation is common among languages such as Spanish, which use the reflective voice.

(4) Equivalence: the process of using a near source-text equivalent in a context where a precise equivalent may or may not exist in the target language. This approach is employed when there is no clear one-to-one equivalent, when literal translation is not possible, or when the word is not important in the text translated. In Khmer, for example, a modifier is placed in front of all cylindrical objects, such as the word “pencil”, which signifies shape. There is no English equivalent translation of this and it is often omitted or translated as the modifier “a”.

(5) Literal translation: the process of translating exactly the word or group of words. For example, the words “the volcano is going to erupt” translated as the target language equivalent of “the volcano is going to erupt”, even if the target equivalent of “the volcano is about to erupt” would be clearer given the grammatical structure of the target language.

Table 1 provides a detailed look at the most frequent word pairs in the Khmer text. It includes the

following information: the Khmer word which was used in the target text (Column 1), the English equivalent in the source text (Column 2), the overall frequency of use of each word in the target text (Column 3), the context in which each Khmer word was introduced to readers for the first time in the target text (Column 4), the frequency with which the word was used along with a picture in the target text (Column 5), the frequency with which the word only was used in Khmer in the target text (Column 6), the frequency with which the word was used as an English-Khmer word pair in the target text (Column 7), the translation technique employed to create the target text (Column 8), and the back-translation of the Khmer word (Column 9).

Table 1
Text Analysis including frequency, introduction, translation technique, and back-translation of Khmer/English Word Pairs

<i>Khmer word from target text</i>	<i>English word from source text</i>	<i>Overall F in target text</i>	<i>Context introduced*</i>	<i>F w/ picture</i>	<i>F w/ Khmer</i>	<i>F w/ E/K pair</i>	<i>Translation technique</i>	<i>Back-translation</i>
កម្ទេចកំណ	Sediment	88	E/K	10	58	30	Transposition	Debris building
ម៉ាក់ម៉ា	Magma	64	K	5	56	3	Transposition & Borrowing	Rock magma
កម្លាំង	Stress	52	K	3	26	28	Equivalence	Force
បរិស្ថាន	Environments	24	K	4	17	7	Literal Translation	Environment
ពង្រីក	Fold	21	E/K	2	18	3	Modulation	Hump bend
ខាងក្រៅ	Extrusive	20	K	1	17	3	Transposition	Side out
បាស	Basic	17	E/K	2	12	5	Borrowing	Basic
ទន្លេ	Fluvial	18	K	4	18	1	Equivalence	River
រំលិល	Shear	15	K	3	6	9	Equivalence	Slip
កំហូចទ្រង់ទ្រាយ	Strain	14	E/K	0	8	6	Equivalence	Damage form
ខាងក្នុង	Intrusive	11	K	2	7	4	Transposition	Side in
សិលាឈូរ	Slate	7	E/K	0	5	2	Transposition & borrowing	Rock Slate
អាស៊ីត	Acidic	6	E/K	0	3	3	Transposition & borrowing	Acidic or acid
ថ្មឱ្យចំ	Sandstone	6	E/K	2	3	3	Transposition & borrowing	Rock Sand
ទន្លេទឹកកក	Glacial	5	Picture E/K	1	1	4	Transposition & equivalence	River ice
មូលដ្ឋាន	Monocline	3	E/K	1	1	2	Borrowing	Monoclinical
អុលីវីន	Olivine	3	E/K	1	1	2	Borrowing	Olivine
ឌីយ៉ូរីត	Diorite	2	E/K	0	1	1	Borrowing	Dyortit
ដែក	Iron	2	K	0	1	2	Literal Translation	Iron
លំនាំប្រក់លើតម្លៃ	Contact Metamorphism	2	E/K	0	0	1	Modulation & borrowing	Transform birth by touch with magma
ផ្គុំទ្រុល	Nappe	2	E/K	0	0	2	Modulation	Bend forward
កម្ទេចកំណផែនដី	Terrestrial sediment	1	E/K	0	0	1	Modulation	Debris building earth
ការពង្រឹង	Cementation	1	E/K	0	0	1	Equivalence	Strengthening
ដីស	Chalk	1	E/K	0	0	1	Modulation	Dirt white
ការបែកបាក់	Fracture	1	E/K	0	0	1	Literal translation	Fracture
វាយ	Strike	1	E/K	0	0	1	Literal translation	Strike

*How the English/Khmer word pair was first introduced in the text. K: Khmer only; E/K: English and Khmer together; Picture: introduced in the caption of a picture.

In Figure 2, we represent the overall frequency of the translation techniques as mentioned in Column 8 of Table 1. Table 1 is based on a sample of the most frequently used 102 word pairs, while Figure 2 is a graphic representation of all of the translation techniques involved in these 102 word pairs. The university teaching team employed the translation technique of ‘modulation’ most frequently - 32% of the time (Figure 2). Words such as “fault plane” became ផ្ទៃរាបបំណាក់ស្រុត or “surface plane breakage erode”. The word “nappe” was also translated using modulation, becoming ផ្គត់ទ្រូល or “bend forward”. Another example of modulation was the translation of the words “terrestrial sediment” to កម្ទេចកំណែផែនដី, which was back-translated as “debris building earth”. With this latter example, the complexity of the translation process is exemplified.

Figure 2. Bar graph of frequency word pair techniques utilized in text.

The next most frequently used technique was ‘transposition’ (20% of the time). For example, the word “intrusive” became ខាងក្នុង in Khmer “side in”. Using this technique, the modifier “in” was

moved to the end of the word, so that it would follow the Khmer grammatical structure. Khmer often strings many nouns together to produce a new word. For example, ‘milk’ is literally translated, “water breast cow”. This is similar to the way the team translated the words “fault plane”.

‘Borrowing’ was used 17% of the time. For example, the words “basic”, “acid” and “magma” are literally “basic”, “acid” and “magma” in Khmer, changing only the signs or letters to represent the Khmer characters and produce the phoneme (or basic sound of the language).

Similarly, the English word ‘diorite’ was translated as ឌីយ៉ូរីត which was back-translated as “dyorit”.

The university teaching team used ‘equivalence’ 11% of the time during the translation process.

For example, the word “stress” became កម្លាំង or “force”. In addition, the word “shear” did not have an equivalent Khmer translation and therefore it was translated as រអិល “slip”. Here, the general meaning was retained even though it is not a direct translation.

The team used literal translation only four times. For example, the word “environment” remained បរិស្ថាន which read “environment” during the back translation. This is not a phonetic translation, however, but rather the use of an equivalent word. Similarly, the word “strike” was translated as “strike” which maintained the exact original meaning. The fact that literal translation was so infrequently used demonstrates the care with which these words were translated.

At other times, the members of the team used a combination of translation techniques. For example, they used transposition with equivalence during the translation of the word “glacial” ទន្លេទឹកកក which was back-translated as “river ice”. They transposed the words “river” and “ice” and employed equivalence by choosing the word “ice”. They used transposition with borrowing when translating the word “slate”. In the back-translation, this became “rock slate”, or

សិលាឈ្នួន in Khmer. Again, transposition was included to place the modifier behind the noun, and borrowing was used for the word “slate”. In addition, the word, “sandstone” became ថ្មឡាថ្ម which was back-translated to “rock stone”. Throughout the text, the word “rock” was repeatedly used in place of the word “sand”. Modulation was used in combination with borrowing one time, when the words “contact metamorphism” became លំនាំប្រែកំណើតដោយប៉ះនឹងម៉ាក់ម៉ា which was back-translated as “transform birth by touch with magma”. Here, several words were moved and added, and the word “magma” was borrowed.

There was one word that the team mistranslated: “desert”. This word had been used as a noun in the source text but was changed into a verb in the target text. It was back-translated; therefore, as “to remove” or “to desert”.

Frequency and Context of Word Pairs

Our study revealed that the university teaching team employed word pairs most frequently to introduce the Khmer word, subsequently using the Khmer word alone without its English equivalent. Mr. Horn described the reason for this word pair:

Usually, when we give a new technical word to the students, as my habit, I have to keep the original word. Cause sometimes if we translate all in Khmer, that means it is easier for the student. But if they read another document for reference in [English] writing - they see the technical word and [it may] seem[to them that] they don't understand. So, we keep the full meaning in Khmer and we explain word by word and we make a movement (a hand motion used to visual[ly] describe the word) and we keep the technical word in English.

After introducing a new scientific word, only the Khmer word was generally used subsequently. For example, the word “magma” was used 64 times throughout the text but only three times with an English/Khmer pairing. Similarly, the word “fluvial” was used 18 times in the text, but only once with an English/Khmer pairing to introduce the word. The latter was probably considered sufficient because “fluvial” was translated with equivalence as “river”.

An exception to the frequent use of word pairs was the Khmer equivalent for the English word

“sediment”. This was used 88 times throughout the translation, and on 30 of those occasions it involved the English/Khmer pair. However, ‘sediment’ was often used as a root word to describe different types of sediment “course-grained sediment”, “terrestrial sediment”, and “fine-grained sediment”. It was therefore often reintroduced with these modifiers.

Another exception was the word, “stress”, which was used 56 times. In 28 of these occurrences, it appeared in an English/Khmer pairing. Similar to the word “sediment”, this word was often associated with different types of stress, such as “shear stress”. Of the 102 word pairs, only nine were used one time. Therefore, repetition of these words was common throughout text.

Pictures were also used throughout the text to help readers understand the scientific text. Very occasionally (three times in total), the team first introduced the scientific words with a picture. This was done twice with a word pair: the words “shale” was back-translated as “rock dish”, and the word “glacial” as described previously. On only one occasion was a Khmer word included alone in the picture: the word “basalt” (back-translated as “rock basalt”). Figure 3 displays several pictures of different rock types, including the word “basalt”, being first introduced to readers. Additionally, it shows an example of a word pair in the text. The word “basalt” is used in combination with its Khmer equivalent. Also the words “extrusive igneous rock”, “andesite”, and “rhyolite” are used with their Khmer equivalent.

រូបភាពទី ៥.២ សំណាកកំប៉ាខាងក្រោមមួយចំនួន : (ក) សិលាក្រានីត (ខ) សិលាឌីយ៉ូរីត (គ) ប្លាបប្រូ និង សំណាកកំប៉ាខាងក្រៅមួយចំនួន : (ឃ) សិលាបាសាល់ (ង) អង់ដេស៊ីត (ច) រីយ៉ូស៊ីត

២. សិលាម៉ាក់ម៉ាខាងក្រៅ (extrusive igneous rock) ។ ម៉ាក់ម៉ាមួយចំនួនរាវណាស់ ។ វានឹងហៀរមកលើផ្ទៃផែនដីរួចបាញ់ចេញពីភ្នំភ្លើង ឬពីទ្រនុងកណ្តាលមហាសមុទ្រជាក់អត់ភ្នំភ្លើង ឬពីស្នាមប្រេះក្រហែង ។ ជាញឹកញយ វាឈាមជាមួយខ្ពង់រាប និងថ្មរឹង ។ នៅពេលវាចេញមកក្រៅ កំអែភ្នំភ្លើងចុះត្រជាក់យ៉ាងលឿន ។ វានឹងឡើងវិញនៅជុំវិញភ្នំភ្លើងក្នុងរយៈពេលតែប៉ុន្មានថ្ងៃ ឬប៉ុន្មានម៉ោង ប៉ុណ្ណោះដើម្បីបង្កើតបានជាសិលាម៉ាក់ម៉ាខាងក្រៅ (សិលាភ្នំភ្លើងខាងក្រៅ) ។ សិលាបាសាល់ (basalt) (រូបភាពទី ៥.២.យ) អង់ដេស៊ីត (andesite) (រូបភាពទី ៥.២.ង) និងរីហ្គីលីត (rhyolite) (រូបភាពទី ៥.២.ច) ជាឧទាហរណ៍របស់សិលាម៉ាក់ម៉ាខាងក្រៅ ។

Figure 3. An example of the introduction of a word pair with a picture. The word “basalt” is introduced here with the Khmer equivalent in parenthesis next to it. It depicts different rock types including igneous rock, basalt, andesite, and rhyolite.

Moreover, throughout the text, pictures were included with Khmer words. This is illustrated by Figure 4, which provides a visual description of folding and faulting process in rocks and shows an example of using pictures with only Khmer words instead of word pairs shown in Figure 3. This technique of including pictures along with the new scientific words was employed 73 times throughout the text.

Figure 4. An example of using pictures in combination with scientific words in Khmer only without their English equivalents. It depicts folding and faulting in rocks.

Discussion

Our data analyses have described and illustrated the different techniques utilized in translating a Geomorphology text from English to Khmer. By resorting to a variety of techniques, the university instructors were able to effectively attune the instructional text to cultural and linguistic differences between the source and target languages. A good translation, as Ercikan (1998b)

points out, reflects not only meaning but also the intent, tone, and context. The employment of more than a mere literal translation served to ensure that both cultural and linguistic differences were being taken into account. As pointed out by Fawcett (2003), the ability to effectively use a variety of techniques is essential for the production of translated texts that target-language readers can understand. Ercikan (1998b) underscores the importance of proper text translation, arguing, that “poor translation can result in misleading or confusing language...” (p. 543). Therefore, it can be argued that the employment of a variety of techniques, combined with a careful consideration of the cultural and linguistic context, has the potential for enhancing the learning of scientific words.

While modulation and transposition are often more difficult techniques to implement, they produce more accurate translations (Fawcett, 2003). Ercikan (1998b) reinforces this view, arguing that a “translation problem occurs when grammatical forms either do not have equivalents, or else have many of them in one or the other language. Syntactical style is one of the most difficult features to carry over from one language to another” (Ercikan (1998b p. 544). In the case of the Geomorphology instructional text, appropriate translation techniques were utilized for words whose translation involved a change in syntactical structures (i.e. in those cases where the grammatical forms of English and Khmer were not similar).

Equivalence is a less desirable technique, as it can often lead to misunderstandings. It was only used, therefore, when the instructors could not translate scientific words using other techniques. Thus, as previously mentioned, “fluvial” was translated as “river”, a commonly used word in Cambodian vernacular. The word “river” or ទន្លេ (pronounced “Ton le” in Khmer) is used on a daily basis in reference to “Ton le Sap” (“big river”), which runs through Cambodia and connects to the Mekong River.

‘Borrowing’ was also important during translation because while certain words could have been translated into Khmer, this might not be the preferred option in cases where more widely accepted English words already existed. Although borrowing occurs in every language and has

been happening for millennia (Sampson, 1985), it is often connected to colonial influences. Attempts to minimize borrowing have been made in certain languages such as French (Fawcett, 2003). Another point about borrowing relates to the language of specific scientific fields. For example, in Cambodia and other Asian countries such as Korea, formulas for chemical compounds are often left in Western scientific nomenclature (Han & Roth, 2006). In the Geomorphology text involved in this study, the compound, SiO₂ was used without any translation on two occasions. Another challenge the team experienced was the actual inability to translate certain words. The team encountered scientific words that no members other than Author Three recognized and he was uncertain about how to best translate these words. In such cases, the team decided to borrow the words from the English language. The word “olivine”, for example, was simply translated and pronounced as “olivine”.

Our data on frequency and word pairings reinforce a point made by Nation (1982) about the importance of repetition, noting that “most forgetting occurs immediately after initial learning and then, as time passes, the rate of forgetting becomes slower” (Nation, 1982, p. 18). Nation also described the significance of presenting word meaning in context, stating that “if a word commonly collocates with another word then meeting these words together will be helpful, particularly for productive use of the word” (p. 22). As indicated above, the university teaching team often repeated scientific words - as much as 88 times throughout the text - constantly reinforcing the acquisition of new scientific words through their repetition in different contextual environments.

As mentioned before, some university students had been introduced to the English word previously, and therefore the recall of this word could be linked to the corresponding Khmer word. Nation (1982) argued for the value of initial word pairs in providing a foundation for further learning. He described the importance of seeing the new target-language word paired with its source-language equivalent before seeing it alone. This technique allows for initial recognition and eventually for word memorization.

Two other points may be noted. Even with careful attention to translation techniques, mistranslation can occur. As described previously, the word “desert” was changed from a noun to a verb. Another important finding was that only three words were introduced using pictures alone, even though pictures were used throughout the text.

These findings relating to translation are also important in the light of the broader function of texts of this kind. RUPP, along with the two university instructors, sought to create a way for university students to have access to scientific information in their mother tongue. This effort led to the production of a text that would be a resource for learning specific scientific words. This responds to Lemke’s (1990) point that there is a specific scientific discourse and essential vocabulary that students need to master in order to effectively participate in discourse in their field (See also Love, 1991). Similarly, Pimm (1984) argues that there is a mathematical register and that “an understanding of the processes involved is essential to anyone attempting to make sense of mathematical speech or writing” (Pimm, 1984 p. 109). Halliday (1975) described a register as a “set of meanings that is appropriate to a particular function of language, together with the words and structures which express these meanings” (Halliday, 1975, p. 65). In contrast to the use of a dialect, which is essentially dependent on users’ group membership, individuals can vary the use of registers based on situations and context, regardless of the group to which they belong. Many disciplines, including science, include specialist words that are not regularly used outside the scientific community : for example, mitochondria and tibia. Even though specialized registers also contain words that are borrowed from everyday language (e.g. “face”, “power”, and “cell”), they have different meanings in science and in everyday vernacular. Many subjects or disciplines, including informational technologies, music, and law, “borrow” everyday words in this way.

As scientific knowledge changes and is adapted over time, so will the language used to express it also change. When more information becomes available, the language becomes more refined to provide more accurate descriptions of improved conceptual understandings. For instance, the replacement of the term, “global warming” with “climate change,” suggests that

social context is important for the proper usage of scientific registers. To take another example, the word “force” has many meanings depending on the type of register that is involved. Scientific or technological context plays a central role in ensuring its correct interpretation. We believe, therefore, that the proper translation of a text into students’ mother tongue is crucial to their acquisition of a scientific register. Of course, the manner in which the text is used in the classroom is also central to its impact on students’ mastery of a scientific register. Future work building on the present study should explore whether and how the kind of text translation described here—when used in the classroom—actually improves student learning.

Conclusions and Implications

The significance of this study for educators is that it identifies some of the key issues involved in the production of good translations of scientific texts in the national languages of postcolonial nations. It also describes some of the translation processes and techniques for scientific words and terms which are likely to lead to the production of high quality L1 texts for students. In particular, like Beacon et al. (2000), we found that the use of back translation was very useful in identifying translation difficulties. Further research into this important approach to analyzing the quality of translated texts is crucial if we are to encourage the adoption of the most efficient translation practices and promote effective scientific instruction worldwide (Oliveira, Colak, and Akerson, 2009). Although there are many online resources that allow for quick translation, these services often employ only literal translation techniques, paying little attention to context or cultural meaning. In many cases, all meaning is lost (Fawcett, 2003). As educators, we need to support teachers in increasingly linguistically diverse classrooms, by providing them with detailed accounts of the kinds of translation techniques and processes that result in good L1 texts, which preserve meaning and which promote the acquisition of scientific concepts.

Because English is the dominant language of trade, commerce, law, and science (Penn, 2005); it has become the language of globalization. There are repercussions, however, for those whose communication, particularly in a learning context, must always be through a second or third

language. In particular, access to scientific literature in developing countries is still marginal at best (UNESCAP, 2007). Thus, the provision of accurate translations of scientific documents that are inclusive of culture is critical to the development of both education and science. The present Cambodian study provides a detailed and specific illustration of how teachers and lecturers might respond to the challenges of translating scientific texts into languages that have not been extensively used in recent times as a medium of instruction at third level. The study is also important, however, in that it is part of the broader effort in many postcolonial countries to promote and restore their native language to its rightful place in education.

By using a variety of techniques, and incorporating the strategies most appropriate for the specific target language, Khmer, the translation team in the present study took careful account of both cultural and linguistic differences between the target and source languages (Ercikan, 1998b). The initial use of English-Khmer word pairs for introducing new concepts and terms, the employment of repetition throughout the text, and the addition of pictures all combined to provide these Cambodian university students with an efficient and culturally appropriate means to learn new scientific words and to master the scientific register of their chosen field (Kellogg and Howe, 1971 Nation 1982; Roth, Tobin, and Shaw 1997). The critical next steps in our research will be to investigate how the translated text is actually used in the classroom and to establish its effectiveness in promoting learning.

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