Teaching Language and Content:

Instructor Strategies in a Bilingual Science Class at a Chinese University

Xiaoping Liang (Corresponding author)
Department of Linguistics, California State University, Long Beach
1250 Bellflower Boulevard, Long Beach, California 90840-0902, USA
Tel: 1-562-985-8509 E-mail: xiaoping.liang@csulb.edu

Sara W. Smith
Department of Linguistics, California State University, Long Beach
1250 Bellflower Boulevard, Long Beach, California 90840-0902, USA
E-mail: sasmith@csulb.edu

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Abstract

The present research analyzes instructional strategies used to integrate the learning of content and English as a foreign language in a bilingual physics class at a university in Shanghai, China. It examines how the instructor handles meaning and form of new English science vocabulary in concept-focused physics lectures and the strategies he used to integrate them. Analysis of classroom instructional discourse and interviews demonstrates that the instructor deliberately employed a variety of strategies to contextualize new terms and to increase comprehensibility of physics lectures. He built on students' prior knowledge of physics, language, and the everyday world. Results support the view that language instruction can be integrated into bilingual science classes at the university level and suggest a variety of strategies for doing so.

Keywords: Language, Content, Bilingual, Science, Physics, English as a foreign language (EFL), Vocabulary, Meaning and form

1. Introduction

As education in many countries has become more internationalized, students may more and more often be expected to learn English in the context of learning content subjects. Recent educational reform in China provides an interesting example. In 2001, the Ministry of Education of China issued twelve suggestions to improve instructional quality of undergraduate education in higher institutions. One suggestion was to actively promote the use of English as a medium of instruction for general education and major-specific courses. Another was to use up-to-date textbooks originally published in a foreign language. In August 2004, the Chinese Ministry of Education released the Assessment Standards for Instructional Quality of Undergraduate Education in Higher Institutions. Bilingual instruction was listed as a major curriculum assessment focus on program development and instructional reform. The evaluation was based on the scale of A (Excellent), B (Good), C (Fair) and D (Poor). One of the standards for scale A was to offer 10% or more courses in programs such as biological technology, information technology, finance, and law through bilingual instruction. Such courses would need to use textbooks in a foreign language and have over 50% of class instruction in that language.

Following these policies, more and more universities in China started to develop bilingual courses to teach content subjects in Chinese and English as a foreign language (EFL) (e.g., Chen, 2008; Li & Wang, 2010; Ma, 2011; Yu & Cheng, 2012; Zhang, 2003). In Fall 2003, for instance, a university in Shanghai alone offered 127 bilingual courses

by Chinese faculty in diverse subject areas such as information systems, multimedia technology, physics, biochemistry, microbiology, marketing, microeconomics, and environmental law.

Hu (2009) detailed the growth of bilingual classes at all educational levels in China and characterized the speed and extent of the bilingual education movement as a 'craze,' proposing that many assumptions about the value of such programs, their academic efficacy or their cultural impact, have not been fully examined. Yang (2011), Zhao (2011), and Sun and Bing (2012) identified factors influencing the effect of bilingual teaching in Chinese universities and proposed strategies for improvement. Kang (2012) suggested that it is important to study 'what is actually happening in college lecture rooms across different academic areas' (p. 32) as part of assessing the quality and impact of such classes.

The present study answers Kang's call. At a general level, it intends to investigate the instructor's strategies in dealing with English as a medium of instruction as well as a focus of learning in a bilingual science class at a Chinese university. More specifically, the study examines how new English science vocabulary is introduced and elaborated in concept-focused instruction in a bilingual physics class. It is a case study based on observations of instructional practice in a natural classroom setting. It uses discourse analysis to examine classroom instructional strategies and interviews to ascertain the instructor's goals and his awareness of the strategies he uses to achieve them (cf. Duffy 2008).

2. Background

Countries from Finland (Nikula, 2005) to Spain (Bruton, 2011) to Malaysia (Tan & Lan, 2011) to South Korea (Kang, 2012) and China (Cargill, O'Connor, & Li, 2012) are encouraging the development of second language skills at a high level to enable students to better participate in the global economy and in professions that rely on selected languages. To meet the twin challenges of developing professional/technical skills and of developing second language skills, many educators have proposed ways to integrate the teaching of language and content (e.g., Dalton-Puffer, 2007; Dong, 2004; Haynes & Zacarian, 2010; Llinares & Morton, 2010; Lyster, 2007). Learning vocabulary is one critical aspect of such language and content development.

2.1 Form-Focused and Meaning-Focused Vocabulary Instruction

Learning vocabulary is considered a high priority for students who do academic study in English (Coxhead & Nation, 2001). In the field of English for academic purposes (EAP), recognition of key vocabulary is believed to facilitate extraction of essential information from scientific and technical texts (Reyes, Briones, Botto de Pocovi, Fortuny, & Sastre, 1997). Technical words are considered context reduced and cognitively demanding because they often carry a heavy information load, construct their own mental reality, and sometimes only make sense in the context of the specialized technical field (Chung & Nation, 2003; Nation, 2001).

The present study draws on an area of ongoing interest in second language (L2) acquisition literature related to vocabulary instruction at any level and in any context: form-focused and meaning-focused instruction. Nation (2001) described meaning-focused vocabulary instruction as a situation in which learners have opportunities to learn new language items through listening and reading activities where the major focus is on conveying information. Form-focused instruction, on the other hand, provides direct teaching and direct learning of the form of vocabulary items such as morphological and phonological features.

In their early studies on instructional strategies in Canadian immersion classrooms, Harley and Swain (1984) and Harley (1993) reported that a focus on meaning alone resulted in high levels of comprehension and fluency but poor accuracy in production. Robinson (2003) echoed these findings and considered a focus on form as an essential instructional intervention, when it is minimally interfering on communicative activities.

Nation (2001) argued for a balanced pedagogical approach in which form-focused and meaning-focused instructions are complementary activities: learners would learn the connection between the spoken (sounds) and the written (word parts, spelling) forms of a word and its meaning. Similarly, Hulstijn, Hollander, and Greidanus (1996) stated, 'Attention must be focused not exclusively on the meaning of the target word, but also on the connection between the word's form and its meaning' (p. 1). Doughty and Williams (1998), like Long (1991), emphasized the need for integration between form and meaning of linguistics items within each learning episode. In their view, it is not enough to simply attend to form and meaning of linguistic input; learners must have a focused attention on the form-meaning association between the two.

2.2 Discourse Approach to Vocabulary Instruction

Theorists in the tradition of pragmatics and discourse analysis (e.g., Adger, 2003; Olshtain & Celce-Murcia, 2003) have added new dimensions to the discussion of how the meaning of terms is learned. First, Olshtain and Celce-Murcia (2003) argue that communication in general and teaching vocabulary in particular depend heavily on the use of common ground. Much physics terminology describes entities that are invisible. To explain physics vocabulary and concepts, a key strategy seems to be finding concrete analogies for the invisible entities through common areas of reference (Arden-Close, 1993), that is, experience and knowledge that are shared between the instructor and the students. These strategies are thought to reduce the cognitive demands of learning new terms by tying them into existing conceptual frameworks.

In addition, Olshtain and Celce-Murcia (2003) argue that terms need to be contextualized (cf. also Mahdavy, 2011; Nelson, 2008). They advocate a discourse approach to teaching vocabulary. 'Vocabulary cannot be taught or learned out of context. It is only within larger pieces of discourse that the intended meaning of words becomes clear' (p. 715). They argue that the intended meaning of a term depends not only on its dictionary meaning but also on 'the contextual frame within which the word appears' (p. 715). They argue further that, in order to enter into a discourse community, students must be able to use vocabulary in appropriate contexts, often interpreting or conveying nuances that are dependent on the context. Similarly, Sfard (2012) argues that mastery of mathematics includes learning how to participate in mathematical discourse. Students thus need to experience terms as used in their technical contexts, and ideally in multiple contexts.

The discussion on building common ground and on contextualizing vocabulary instruction seems especially relevant to understanding the role of the instructor's classroom discourse. We are interested in finding out how the instructor builds on common ground in order to provide comprehensible input for students and how he provides multiple contexts in his lectures for the appropriate use of new terms.

2.3 Research Questions and Rationale

In light of the above aims, the present study examines an instructor's treatment of English science vocabulary in bilingual physics lectures. The specific research questions we ask are: 1) How does he attend to and integrate form and meaning of new English science vocabulary? 2) How does he introduce and contextualize new science vocabulary in lectures? 3) What are his goals with regard to teaching vocabulary and how are his strategies related to them?

A case study approach was used in order to provide a 'rich analysis' (Duff, 2008) of one instructor's classroom strategies. We chose naturalistic observations of classroom language with discourse-analytic methods for identifying strategies used. We also held formal and informal interviews with the instructor to allow him to explicitly identify his goals and strategies. As Duff notes, the combination of interviews and observations allows us to triangulate; that is, to see his strategies from two points of view. Morton (2012) used this methodology to analyze classroom talk from a constructionist point of view, in this case pointing out discrepancies between an instructor's stated goals and observed classroom discourse.

Leung (2005) and Adger (2003) both note that most research on second language learning in an academic setting has employed research methodology designed to compare outcomes as assessed, for example, by exam scores. While this has yielded valuable insights, they argue that the study of classroom discourse also has unique contributions. It 'has become an increasingly attractive analytic method for researchers in second language learning because of what it can show about the process and what it can suggest about second language pedagogy' (Adger, 2003, p. 511). Leung (2005) argues that 'close-up interaction data' (p. 238) can show how language is actually used by teachers and students in a particular context, which can then contribute to wider discussions on practices and policies in bilingual education. Barwell (2005) argues similarly regarding the need for analyses of classroom language in understanding how math is learned in a second language context.

3. Methods

The present research consists of a case study of a physics class at a university in Shanghai, China, where the instructor and the students were all native speakers of Chinese. The class was taught mostly in English in order to help students develop their English language skills, while the focus of the class was on learning physics.

3.1 Research Site and Participants

The study was conducted in a beginning level physics class for university freshmen in their second semester. The textbook was originally published in English by an American publisher. It created a high language learning load in

terms of vocabulary and reading. In the course syllabus written in English, the instructor clearly described the challenge:

> 'This book is a bit above standard level of university physics course. … The disadvantage of this book for the Chinese students is its size, 1400 pages of all! Students are requested to read 20 pages (about 13,000 words), or more, for each two-period session.'

The 35 students (two female and 33 male) in the physics class were waived from the nation-wide university entrance examinations because they all won places in math or science contests at the city, provincial or national levels. They applied to take this physics class offered in English, took a written English test and a physics test administered by the course instructor, and were selected based on their test scores.

The instructor has a Ph.D. in physics from a Chinese University. He learned English in China as a required component of his education and spent one year as a visiting scholar in a physics laboratory at Harvard University in the United States. Although he was not trained to teach EFL, he developed a bilingual instructor training program that included English language skills and instructional strategies during his appointment as the Associate Dean of Academic Affairs. He was assigned the bilingual physics class because he had taught it a few times and is considered especially successful as an instructor.

At the time of the study, he was teaching two sections of the class to students of two different programs. In the class under observation, he was not rigid in his use of English. While lectures and power-point slides were mostly in English, he welcomed questions in Chinese, sometimes clarified a point in Chinese, and had casual conversations in Chinese during class breaks. The class was held in a typical Chinese university lecture hall with rows of desks and chairs. The instruction was mostly lectures, but the instructor often invited student questions and structured some group discussion from time to time.

3.2 Data Collection and Analysis

This research employed two methods for data collection. It used observation in natural classroom settings to obtain instructional discourse that uncovers how the instructor attended to and integrated the form and meaning of new English science vocabulary and how he contextualized new technical terms in lectures. The instructor agreed to have his class videotaped for research purposes, but was not aware of the specific interests of the researchers. Therefore, he did not tailor the class to the goals of the research and his lectures mirrored what would be happening without researchers' presence.

In total, 10 two-period sessions of physics lectures (one hour in each period, 20 hours in total) were recorded and transcribed in their entirety for analysis. This paper is based on two hours of instruction on wave forms and wave motions. Instances of vocabulary teaching were identified and analyzed to reveal the strategies used.

A teaching episode (i.e., an activity involved in introducing a term) was identified as form-focused when the instructional discourse focused on grammatical, morphological, or phonological aspects such as parts of speech, word parts, spelling, or pronunciation. It was identified as meaning-focused when the focus was on content information and relations with other concepts.

A five-hour interview was conducted in Chinese to gather the instructor's goals of vocabulary instruction and his awareness of the strategies he used to achieve them. The audio recording of the interview was transcribed in its entirety for analysis. The instructor's reasoning for his strategies in teaching the form and meaning of new English science vocabulary were identified to triangulate the observation data and were translated into English. In addition, informal interviews during the 10-minute break between two class periods and immediately after class were also carried out to capture the instructor's reflections on his instructional practice.

4. Results and Discussion

Analysis of classroom discourse demonstrates that the instructor took an integrative approach in dealing with form and meaning of new English science vocabulary. He employed a variety of contextualizing strategies to lighten vocabulary and reading load and increase comprehensibility of texts and lectures. We also note the role of metapragmatic expressions (cf. Smith & Liang, 2007) in guiding students' processing of new concepts, especially when there was evidence of student uncertainty. Examination of the interview data shows that the instructor had clear goals with regard to teaching vocabulary and he was intentional in the strategies he employed in order to achieve these goals.

4.1 Integrating Form- and Meaning-Focused Vocabulary Instruction

In answer to research question one, analysis of classroom discourse reveals that, in introducing a term, the instructor sometimes focused on meaning alone, but usually he dealt with both the form and the meaning within one teaching episode.

4.1.1 Focusing on Meaning

The instructor typically focused on the meaning of new terms by providing definitions, synonyms, or examples. In Excerpt 1, he defined the new term 'coherent' in everyday language to help students understand its general meaning before using it in its technical context. He also used the metapragmatic expression 'mean(s)' three times to signal his definition of 'coherence'. This all occurred in the context of his explanation on wave motion.

Excerpt 1:

Coherent, **that just means they are related**. Understand? Makes sense? … so what, **what do we mean** '**coherence in optics**'? In the waves, **in the wave motion**, **that means these waves and that waves has a definite relation**.

In Excerpt 2, he used the word 'stripe(s)' to paraphrase the physics term 'fringe' in explaining the concept of incandescent light. To make certain that students understood the meaning of the word, he invoked their presumed knowledge of zebras.

Excerpt 2:

And you'll never find any fringe. You understand fringe? **Fringe is a lot of stripes**. **Dark**, **bright**, **dark**, **bright**, **dark**, **bright**. A fringe, understand a fringe? Right, fringe, **a fringe is a stripe**. Understand? … You understand the **zebra**. … Okay, you understand **zebra**, **a lot of stripes**.

4.1.2 Integrating Meaning with Form

The instructor used a variety of means to integrate form-focused and meaning-focused instruction within a given introduction to a term. While concentrating on meaning, the instructor sometimes highlighted word parts, spelling, and/or parts of speech. In Excerpt 3, in elaborating on the concept of periodic function, he presented an explanation of how English forms the opposite meaning of a word through the use of prefixes. He emphasized the prefix in the word 'aperiodical' to raise students' morphological awareness. He also noted the difference between prefixes and separate words before returning to the use of the term in physics.

Excerpt 3:

In English … **if we try to get opposite meaning**, **we can put it in a prefix**. Got it? Understand? But this prefix can be 'in', can be 'im', can be 'un', can be 'non', can be 'counter.' But this word is very different. **You just put an** '**a**.' Now, **this** '**aperiodical**', **not a** '**periodical**.' **And guess what? Now, NOT periodical**.

In Excerpt 4, the instructor explained the term 'temporal.' He started with an everyday word 'time.' Then, he made a meta-pragmatic remark, that it is an academic word. Next, he introduced the target word 'temporal' and defined its meaning. Lastly, he drew students' attention to its part of speech 'that's an adjective.'

Excerpt 4:

Sometimes we say 'time.' But sometimes, it's a, it's a very academic word, we call this '**temporal.' That's just about time**. … Alright, **that's an adjective**.

In Excerpt 5, the instructor made several integrations between the meaning and the pronunciation of the word 'truncate' to help students connect its meaning and its phonological form. First, he defined it. Second, he called attention to the phonological form by asking students to repeat the word after him twice. Third, he drew on the blackboard to demonstrate the meaning of the word. Fourth, he enunciated the word twice. Lastly, he again directed students' attention to the meaning of the new word with the paraphrases 'cut off' and 'cut it off' and with a more playful paraphrase 'kick off all the rest.' In addition we note that he used both the present and the past tense.

Excerpt 5:

And then you make an estimation. How many harmonics I have included. I think just a few. Sometimes, they will be truncated. You understand 'truncated'? … '**Truncated**' **is just cut off**. **Can you say truncate**? **Truncate.** (DRAWS ON BOARD). **I hope that you can pronounce it** by yourself. I jus, **I just articulated it**, **truncated**, **trun-ca-ted** … I just **cut off here**. I can just **kick off all the rest**. So we got this one. … Understand? Because, **here, we cut it off, truncate it**.

4.2 Strategies for Introducing and Contextualizing New Vocabulary

In answer to research question two, analysis of classroom discourse suggests that the contextualizing strategies the instructor used to teach new technical terms fell into three categories: 1) activating students' prior knowledge as a context for introducing the meaning and form of a new term, 2) establishing meaning and making form-meaning connections, and 3) monitoring and consolidating comprehension of new vocabulary.

4.2.1 Activating Prior Knowledge as a Context for a New Term

Many of the instructor's strategies may be thought of as ways to contextualize the new vocabulary (Nelson, 2008). By providing verbal and nonverbal contexts, the instructor made an effort to connect the mental abstractions of physics to students' everyday life experience with the physical world. In this way, students could connect new terms with previously established concepts, reducing the cognitive demands of learning the new term. Specifically, he activated students' prior knowledge of physics, of everyday life experience, and/or of language as a basis for introducing the meaning and form of a new term.

4.2.1.1 Activating prior knowledge of physics

As students in this study were already accomplished in the subject matter, the instructor was often able to use their prior knowledge of physics as a context for introducing the meaning of a new term. For example, in Excerpt 3, the instructor elicited students' knowledge of the recently taught concept of periodic function. He used the familiar word 'periodical' as a meaning holder and then built on its meaning to introduce the new term 'aperiodical.'

4.2.1.2 Activating prior knowledge of the everyday world

The instructor frequently used everyday experience as a basis for his explanations. For example, in Excerpt 2, he introduced the technical term 'fringe.' To define it, he first gave the paraphrase 'stripes.' To make sure that students understand the meaning, he then built on more familiar everyday knowledge, that zebras have stripes, to help them infer the meaning of the term 'fringe.' In other cases he provided an analogy from everyday life to illustrate a meaning, as in Excerpt 8 when he used the familiar setting of a swimming pool to convey the meaning of 'plunge' in the context of wave motions. Further, in some cases, he gave an elaborate scenario from everyday life to provide a context for the new term. In Excerpt 9, he introduced the term 'destination' in the context of wave theory. Following a comprehension check in which students seemed uncertain of the meaning, he provided an elaborate context from everyday life in which to use the term—students going to the dining room when hungry. While some might consider these to be digressions from the physics lecture, we believe they play the important role of grounding the terms in students' preexisting conceptual frameworks.

4.2.1.3 Activating prior knowledge of language structure

In other examples, the instructor activated students' prior knowledge of English morphology or grammar, to help them see the form or the structural function of the new word. In Excerpt 4, he built on their knowledge of grammar, noting that the new word 'temporal' was an adjective, in contrast to the familiar noun 'time.' In Excerpt 3, he built on their prior understanding of morphology, explaining the function of prefixes in changing meaning and listing examples that might be familiar. Then he noted specifically the role of the prefix 'a' in the new word 'aperiodical.'

4.2.2 Making Form-Meaning Connections, Explicitly and/or Implicitly

To establish meaning and to make terms more accessible, the instructor used a combination of explicit and implicit strategies. In many examples, the explicit focus was on defining the meaning, while the attention to form was implicit in the repeated pronunciation and visual presentations of the word. In other examples, the instructor explicitly dealt with both meaning and form. In most cases, the instructor used multiple strategies to make the meaning clear and to create multiple connections to relevant contexts.

4.2.2.1 Explicit vocabulary instruction

The instructor made an effort to explicitly teach students new technical vocabulary as needed. The standard explicit strategy for defining a term is to give a synonym and/or a brief definition. Excerpt 6 illustrates several of the instructor's explicit instructional strategies. He first introduced the word 'transcend' in the context of general rules of wave motion. Then he explicitly defined the word 'transcend' as meaning 'overpass, has nothing to do with.' Third, he defined the term in the context of wave theory as 'has nothing to do with the nature of the medium.' Fourth, he gave examples of relevant media and waves. Finally, he restated the meaning in the context of wave theory.

Excerpt 6:

There are two general rules of wave motion that **transcend** the nature of the medium or types of waves. **You understand 'transcend'**? ... **overpass, has nothing to do with. That**, right, **that means** uh, that general rule, **that general problems of the wave motion that has nothing to do with the nature of the medium**. That medium could be string. That medium could be glass. That medium could be liquid. That medium could be solid. … Now, a wave can be light. It can be sound. It could be anything else. … Right. These problems are general. They're not very specif, not specific, specific. **It has nothing to do with the problems of the medium**.

4.2.2.2 Implicit vocabulary instruction

Examples of implicit vocabulary instruction were also plentiful. The instructor might demonstrate with a gesture or object to suggest the meaning of a word. In Excerpt 7, he first introduced the concept of waves that deform, 'sometimes the ray is not in a straight line, but it's folded.' Then, he checked comprehension of 'fold.' To ensure that all students understood, he took a piece of paper and folded it, making sure that everyone saw this action. Clearly, the instructor was intending for the students to infer the meaning of the term 'folded' from his actions, but he never stated that directly. Lastly, he verbalized his action by saying 'I just fold a piece of paper. This is fold.'

Excerpt 7:

Sometimes, **the ray is not in a straight line**, **but it's folded**. Understand 'fold'? Understand 'fold'? Okay? Yes? (NODS AT STUDENT). Good. Something like this. **(FOLDS A PIECE OF PAPER)** … **I just fold a piece of paper**. **This is** '**fold**'**.**

Another implicit strategy was to give examples of everyday uses of physics terms in order to help students infer the meaning of the term as used in physics. In Excerpt 8, in discussing the superposition of waves, he used the term 'plungers.' He first showed a slide of two concentric circular waves produced by two plungers. Then he provided an example of the word as a verb form and in a usage more likely to be familiar to students, that is, to plunge into a swimming pool or a lake.

Excerpt 8:

So first, let me give you example. Two concentrated circular waves, produced by two nearby oscillating **plungers**. … Okay, '**plungers**' **something like this**. It's uh, **you can see it like this**. **You plunge into water**. Got it? **There is swimming pool**. **Or, you can plunge into lake**. **You plunge into water, and you soak yourself**. Understand? **You wet yourself**. You plunge into water.

4.2.2.3 Integrating explicit and implicit instruction

The instructor usually integrated explicit and implicit instruction in the same teaching episode. In Excerpt 9, in explaining wave motion, he used the term 'destination' in a technical context. Next, he noted the importance of the concept. Then, he checked students' understanding of the term. Fourth, he explicitly defined it. When students failed to respond he tried to help them infer the meaning, using implicit instruction by giving an example of everyday usage.

Excerpt 9:

Waves taking different routes to the destination suffer different phase shifts. So this is very important. That's a crucial difference. You understand though … you don't understand '**destination**'? '**Destination**' **that means**, **that's aim or goal.** … Got it? **When you want to have lunch**, **right after these morning classes**, **and you go to the dining room**. The dining room, you go and have lunch. The dining room, **the dining room is a destination**.

4.2.3 Monitoring and Consolidating Comprehension of New Vocabulary

The instructor was aware that vocabulary was a major challenge to students' understanding of the textbook and his lectures. He both anticipated potential problems and also remained alert for problems during his lectures. Thus he frequently checked students' comprehension of new words and adjusted his instruction accordingly.

Metapragmatic language (Smith & Liang, 2007) played a regular role in these lectures. In all nine examples, he used some form of comprehension check. Sometimes he asked general questions such as 'Makes sense?' (Excerpt 1), 'Understand?' (Excerpts 1, 2, 3 and 8), 'Got it?' (Excerpts 3 and 8). Other times he asked questions regarding a specific word such as 'You understand fringe?' (Excerpt 2), 'Understand fold?' (Excerpt 7). When he sensed a comprehension breakdown, he stopped the flow of his lectures to give a quick definition (Excerpts 1 and 2) so that

students could continue following the content. In other cases, the comprehension check led to a long digression, as followed his use of the term 'destination': 'You don't understand destination?' (Excerpt 9).

The instructor also used a variety of means to consolidate students' comprehension of the meaning and usage of the terms. When he was presenting a pre-planned part of his lecture, his grammar was formal and well-formed by U.S. standards. However, when elaborating on the meaning and form of a new concept, he used a variety of strategies we consider 'play' (cf. Rimmer, 2011). This included numerous repetitions in various forms 'truncate … truncated' and with different prosody 'trun-ca-ted.' It also often included the use of nonstandard forms, for example, 'these waves and that waves' and the use of slang terms such as 'kick off all the rest.' These variations may be seen as means of consolidating vocabulary meaning by showing a term's use in a variety of contexts. Also, as Rimmer proposes, this play may serve other purposes--to provide 'a sense of ownership of the second language which is critical in forging a linguistic identity' and to build 'a deeper relationship between participants' (p. 26). The meta-message is that it is more important to play with the language than to just use it in a formal way.

4.3 Teaching Vocabulary Intentionally within the Context of Teaching Physics Concepts

In answer to research question three, the interview data show that the instructor had clear goals for teaching vocabulary and was deliberate in the strategies he employed in order to achieve these goals. His general objective for the bilingual physics class was to prepare students to function as part of an international community of academics and professionals, where much of the literature and communication is in English. With regard to language development, he made it clear in the course syllabus written in English that building vocabulary was a course goal: 'students will greatly improve their reading comprehension and build a big vocabulary … (one of the goals of this course).'

Examination of interview responses shows that the instructor was clear about his dual roles as a bilingual content course instructor. In the following interview excerpt, he acknowledged the complex challenge he faced:

> 'I have played a dual role in reality. That is to say, I am a physics instructor, but I have also acted as a foreign language instructor, whether you admit or not.'

He was aware of student motivation in taking the bilingual physics class and believed that students could learn both physics concepts and the English language through bilingual instruction:

> 'These students like the content of this course. They may not be interested in English. But they would learn the language when taking the bilingual physics course. I call this "learning content as a goal and learning language as a byproduct."'

His instructional strategies seemed to be build around his goal of helping students learn both physics and English. In relation to teaching new vocabulary, he provided a thoughtful rationale for his approach of providing multiple contexts of physics terminology:

> 'Many students believe that words I use in physics lectures are specific to the field. I want to let students know that in many science fields, words specific to the field are very few, no more than 10%. Some words look very difficult. They are in fact still everyday English. … They have dual functions and can be used in both science and everyday life. They are very useful. For example, the word "coherence" has specific meaning in physics. It's a specific term used in the study of light. … It refers to two lights having some kind of connection with each other, a very important term in modern physics. Coherence is a physics concept with a definition specific to physics. … But if you tell them that "coherence" can also be used in everyday life, their vocabulary would be enlarged. I feel I should play this role.'

Providing synonyms of new science vocabulary is another approach he employed in his lectures. His interview reveals his reasons for this deliberate strategy:

> 'Sometimes, I would emphasize a key technical term by providing a synonym. I do this intentionally. Although I do not expect students to learn both words, I do hope this would help students realize that this is an important term. To help students remember the term, I would need to check the dictionary for synonyms. … Take for example the word "use." If I always say "use this equipment", students would think that "use" is the only possible word in this context. On the other hand, if I say "use" in one sentence and "employ" in the next, it would make my explanation less boring. Secondly, students would do the same in their written assignments by not using the same word repeatedly.'

The following interview excerpt presents another explanation for his strategies of providing synonyms and multiple contexts of physics terms:

> 'In physics, if two things interfere with each other, we would say "constructive interference" or "destructive interference." I would tell students that "constructive" and "destructive" are also everyday vocabulary. You can say "a constructive suggestion" or "a destructive suggestion." … Instructors can give constructive suggestions or positive suggestions. Then students would know that "positive" and "constructive" are synonyms and are related. Otherwise, they may not know the connection.'

Integrating language instruction with content instruction appeared an important goal for the instructor. He repeated this goal in the following excerpt and gave another example of the strategies he used to achieve his goal. The example illustrates his awareness of English morphology and his deliberate practice of teaching it in the context of physics.

> 'I teach physics, but I have to take English into consideration. For example, when students come across a new word, I would explain to them the word root, the relation between this word and its root, and its meaning. There are many compound words in science. Also, an antonym can be formed by adding a prefix such as "in", "im", "counter", and "anti." Some prefixes are not so common. It would be helpful to inform students of them. For example, the word "periodic." By adding an "a", it becomes "aperiodic", an antonym of "periodic." I believe very few students would know this prefix.'

5. Conclusions

This study examined instructional strategies in a bilingual physics class at a Chinese university. In our analysis of the classroom discourse, the instructor did appear to meet the challenges of integrating the teaching of content and language. Both interview data and analysis of classroom discourse indicate that he played an active and deliberate role in teaching vocabulary, all within the context of teaching physics content. He used diversified strategies to contextualize new technical terms. He explained and elaborated on their meaning, providing direct definitions but also building on students' prior knowledge of physics, language, and the everyday world. He also provided multiple examples of authentic language using the terms in context, providing models for how they will be used in the discourse community of physics. In integrating the meaning and form of new terms, he used a variety of explicit and implicit strategies to help students acquire different aspects of lexis.

The results of this study are of potential importance to pedagogy of bilingual content classes. They indicate that there is a place for language instruction in bilingual content classes such as physics and that it is possible to not only teach content in EFL but also to teach EFL through content. The instructor's explanations of and elaborations on physics terminology and concepts provided authentic input for content as well as language learning. We hope that these findings encourage bilingual content instructors to integrate English with the subject matter they teach and to provide students opportunities for simultaneous development of content and language (Mohan, 1986).

We also hope that the results will encourage further research on how English is used in various academic and international contexts. We believe it important to recognize the limitations of existing bilingual content classes (e.g., Hu, 2009), caution about the general educational and social impact of such classes in some contexts (e.g., Bruton, 2011), and look for solutions to improve their effectiveness. We also believe it imperative to identify features of the instructor's style and of the students' skill and motivation that affect the success of these classes. With fuller knowledge of what is actually happening with teaching and learning in the classroom (cf. Kang, 2012), we can hope to better understand the role of English as a medium of instruction as well as a focus of learning in bilingual content classes. We hope we have demonstrated that the analytic tools of discourse analysis can contribute further to this discussion, along with other research methodologies.

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