Despite broad differences in their math or English backgrounds, college-bound students of widely varied first languages share the identical need for explicit English language instruction to recognize, manipulate, and communicate math terminology in English. For a simple experiment, try to orally describe the following formula in a second language:

\[ \frac{3,116}{9a^2} = b^4 - 10.4 \times 6c^3 \]

If you found that task difficult to accomplish, you are not alone. Attempting to articulate math problems usually frustrates most second language learners, yet teachers commonly assume that nonnative English speaking students will have little trouble with math comprehension because of the erroneous belief that math is exclusively numerical. We have found this assumption to be incorrect. The language of math (e.g., discussing equations, explaining word problems, and using jargon) is rarely included in any English as a second language (ESL) or English as a foreign language (EFL) curriculum. As a result, students struggle in their introductory college or university math courses as they simultaneously attempt to acquire math concepts and language.

This chapter addresses these shortcomings by describing two English for specific purposes courses, one in Muscat, Oman on the Arabian Peninsula, and the other in Seattle, Washington, in the United States. Specifically, we identify the problems facing ESL/EFL math students, present our curricula and materials for our students in both ESL and EFL contexts, and provide our reflections on challenges and the need for further curriculum development.

**CONTEXT**

We began our research independently on opposite sides of the world at North Seattle Community College (NSCC) and at Sultan Qaboos University (SQU)
when we each noticed that our English language students were constantly struggling in their math classes. By conducting research on students and math professionals at our institutions, we found extraordinary parallels in the students’ deficiencies in the language of math, despite the vastly dissimilar contexts.

NSCC students need to complete math courses as part of the requirements for most degrees, whereas at SQU, students in the sciences, engineering, medicine, agriculture and commerce must complete several math courses as part of their degree programs. In both institutions, the language of instruction is English; the textbooks and materials also are in English. Most students at SQU enter the university after graduating from high schools where content courses are taught in Arabic. An entry placement test allows students with strong English skills to enter the university math courses directly. The vast majority do not pass this English test, however, so an intensive English program (IEP SQU) is provided to help bridge the language gap. The maximum time allowed for students to study in the IEP is 1 year. Students at NSCC face similar requirements: They must pass an English placement exam in order to enroll in regular college courses. If their English is weak, students must attend and pass NSCC IEP classes before continuing their education at NSCC; however, they do not have a time limit for completing their language courses. The profiles of NSCC and SQU students are summarized in Table 1.

To inform our curriculum development work, we interviewed math professors at NSCC and SQU with questions, including: What are the greatest math

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<th>Table 1. Student Characteristics</th>
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<td><strong>Description</strong></td>
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<tr>
<td>Gender</td>
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<tr>
<td>Age</td>
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<tr>
<td>Native language</td>
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<td>Education (highest level)</td>
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<tr>
<td>Math education</td>
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<tr>
<td>Math attitudes</td>
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<tr>
<td>Income level</td>
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<td>Funding for education</td>
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<td>Employment</td>
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needs of your students? What difficulties did they have last semester, and how did you address them? What specifically do you want your students to be able to do in order to succeed in your math courses? Do you have specific examples of language problems that your students have had? At both institutions, virtually identical frustrations were expressed: Students cannot understand or use basic math terminology, and students cannot ask questions about math when they seek clarification. Math professionals at NSCC and SQU further identified weak reading skills as a factor in students’ difficulties with word problems.

At both NSCC and SQU, high failure rates in math courses prevent students from graduating from college or pursuing their career goals despite the fact that many had mastered college math in their first language. At SQU, this was surprising because most students entered the university with high math scores and strong confidence in their math abilities. This paradox resulted in the search for an explanation and remedy. Prior to entering university math courses, we asked students to orally produce a series of numbers, to verbalize simple equations, and to explain elementary word problems. This student-based research revealed three main trouble spots:

1. **Math jargon problems**: ESL/EFL students misunderstand, do not understand, or are unable to produce key words and phrases, including those in word problems.

2. **Cultural reference problems**: Math textbooks and faculty frequently use cultural references that distract or overwhelm the students.

3. **Strategy problems**: ESL/EFL students have difficulties solving word problems, even when they understand all the vocabulary.

Although some strategy problems are also conceptual (native speakers have the same problem), ESL/EFL students clearly have contributing language complications.

**Math Jargon Problems**

College and university math professors expect their students to know basic math terms and to be able to use them without hesitation. Math teachers have a great deal of required content to cover in class and have no time to spend explaining or teaching basic math terminology. However, students in Seattle and Oman could not use or understand elementary math vocabulary, so they were left to work out meanings while they studied advanced concepts. Specifically, students in each of our studies lacked jargon awareness in several areas:

1. Although most of the students could produce *plus* and *minus*, few knew *multiply* and *divide*.

2. Almost none of the students who did know these basic terms were able to use *by* or *into* with the verb *to divide*. For example, “8 divided by 2
equals 4” is not the same as “8 divided into 2 is 4.” The latter, of course, is incorrect. Another common error was for students to say, “8 divided 2 is 4.” Without a crucial preposition, this math problem is completely bewildering, as the listener does not know which number is the divisor.

3. SQU students did not know how to say fractions, decimals, exponents, or large numbers such as 111,011.

4. Fundamental geometry terms such as angle and area, and more specific terms like right angle, were unknown.

5. Homophones (and near homophones) caused students great difficulties understanding the rapid speech of lectures and comprehending word problems:

   - angle/ankle
   - area/era
   - before/four/for
   - column/calm
   - divisor/advisor
   - eight/ate
   - exchange/change
   - factor/factory
   - flower/flour
   - give/keep (for Arabic speakers)
   - in/an
   - know/no
   - many/money
   - meet/meat
   - one/won
   - pair/pear
   - quotient/quota
   - remainder/remain a/remain the
   - son/sun
   - sum/some
   - tens/tense
   - two/to
   - vary/very
   - weigh/way

Although it is clear that a math teacher would be unlikely to use certain words in place of others (e.g., ankle in place of angle), the confusion and difficulty lie in the distraction to the students as they take valuable seconds away from listening to the math instruction in order to sort out the correct meaning.

Other jargon proved challenging because of a general as well as specific, content-based meaning. The following words are usually first learned in other contexts with different meanings. For example, table is usually learned as a piece of furniture where we place items or where we eat. However, in math, a table, of course, is similar to a chart. Similarly confusing words include:

   - area
   - even
   - group (noun and verb)
   - last
   - left
   - lighter (adjective vs. noun)
   - measure
   - order (noun and verb)
   - place
   - power
   - rational
   - root
   - shaded
   - square
   - steps
   - times
   - trade
   - value
Cultural References Problems

Textbooks in both North America and Oman are U.S. publications. Publishers try to make the books relevant to young students in the United States; therefore, they include great numbers of cultural references like U.S. geography, stock markets, and baseball. The metric system is used in some math textbooks, but the nonmetric system is still prevalent. The teachers at NSCC further frequently use cultural references in their lectures, and the teachers at SQU, although usually not American, are also accustomed to using the references from the textbooks. However, one professor at SQU, an Egyptian, successfully instructs his students to change all U.S. geographical names to \textit{Point A} or \textit{Point B}, and to change unfamiliar measurement terms (e.g., miles, inches, quarts) to \textit{units} in order to enable the students to focus on the math and not be distracted by extraneous information.

Strategy Problems

The strategies for solving word problems involve reading skills as well as analytical competence. All math students must (a) recognize the goal of the problem, (b) identify the given information, and (c) construct and solve an equation. This may be difficult for even native speakers, but second language learners must first understand the language and then work out the problem. Students at both NSCC and SQU had difficulties with the vocabulary and phrasing of word problems as well as confused commas with decimal points. Four examples of such misunderstanding follow:

1. 1 out of 10 = 90%. Every student in two classes at SQU erroneously believed that “one out of ten” referred to the “nine” that remained after the “one” was extracted.

2. $8.642 \times 10 = 86.42$ or $86,420$? In the majority of countries around the world, the comma and period—or “dot”—have different math functions than those in English. Therefore, for many students, $8,642 \times 10 = 86,420$ (commas used for thousands) and $8.643 \times 10 = 86.42$ (dots used for tenths) are extremely problematic. In fact, except for Mexico and Peru, all of Latin America uses commas and dots differently from English countries. Similarly, except for the United Kingdom, Ireland, and Switzerland, all of Europe uses commas and dots as Latin America does. Historically, Middle Eastern countries used a system of slashes to mark math figures, but they have since incorporated the commas and dots of the majority of Europeans. Most of East Asia, including the People’s Republic of China, has the same usage as English speaking countries (Wikipedia, n.d.).

3. “How many are left?” is interpreted as the items that were removed instead of those that were remaining. Both NSCC and SQU students
believed the question, “How many are left?” referred to how many of the items or people had been removed or had left an area. Even after having this explained in detail, students had considerable difficulty remembering that “How many are left?” was the same as “How many remain?”

4. “. . . in all?” This short phrase created great confusion with SQU students. They simply did not understand the concept. Compounding this particular comprehension difficulty was the common question, “In all, what was left?” or, even more confusing, “In all, how many are left?”

**CURRICULUM, TASKS, MATERIALS**

Recent cognitive science research has shown the value of repetition in memory and learning, which is especially useful in language and content learning. Curran (2000) demonstrates that memory, familiarity, and recollection arise from distinct neurocognitive processes, thus aiding learning and retention. Although numerous studies focus on the crucial need for repetition in second language learning, classroom practice of the past two or three decades has employed little repetition, perhaps to avoid the appearance of old drill-and-kill methods. However, the very nature of frequency “actively contribute[s] to retention of words” (Ruchkin et al., 1999, p. 345) and influences neural organization (Federmeier & Kutas, 1999).

Griffin and Bock (1998) argue that we retain words in memory according to “phonological encoding by word frequency” (p. 313) or, the more phonological input, the more the brain stores words and phrases by sound. Repetition also applies in literacy learning, as demonstrated in *The Rereading Effect* (Rawson, Dunlosky & Thiede, 2000). These researchers state that “rereading improves metacomprehension accuracy” (p. 1004). Even physiologists find that through repetition, the very control center of our cells, the mitochondria, adapts and is actually physically altered (McArdle, Katch, & Katch, 1994). For these reasons, we integrated repetition through games and other activities to maximize student learning of the language of math.

**In Seattle, Washington, United States**

NSCC offers Math 070: Basic Math for ESL and Limited English Proficiency (LEP) Students in preparation for taking basic math and basic algebra courses. Math 070 consists of (a) daily classes (1 hour each weekday), (b) pair work and board work, and (c) weekly tests, including oral components. (For a list of course topics, see Table 2.) Every class includes oral practice both in pair work and at the white board in front of the class. Although teachers may be hesitant to have students perform the latter because of potential student embarrassment, all students struggle equally with the English of math, so they are sympathetic and patient with each others’ mistakes as well as supportive of the teacher’s public corrections. Because they learn from one another, the classroom atmosphere
The English of Math—It’s Not Just Numbers!

Table 2. NSCC MATH 070 Basic Math for ESL and Limited English Proficiency (LEP) Students

<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
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<tbody>
<tr>
<td>Week 1</td>
<td>Introduction, problem solving, and whole numbers</td>
</tr>
<tr>
<td>Week 2</td>
<td>Common fractions: addition, subtraction, and multiplication</td>
</tr>
<tr>
<td>Week 3</td>
<td>Fractions: division and combined operations</td>
</tr>
<tr>
<td>Week 4</td>
<td>Decimal fractions: operations</td>
</tr>
<tr>
<td>Week 5</td>
<td>Review, catch-up</td>
</tr>
<tr>
<td>Week 6</td>
<td>Decimal fractions and common fractions, percentages</td>
</tr>
<tr>
<td>Week 7</td>
<td>Averages, estimates, ratios, and proportions</td>
</tr>
<tr>
<td>Week 8</td>
<td>Measurements: length, mass, volume</td>
</tr>
<tr>
<td>Week 9</td>
<td>Measurement instruments, paycheck calculations</td>
</tr>
<tr>
<td>Week 10</td>
<td>Review</td>
</tr>
<tr>
<td>Week 11</td>
<td>Final exam</td>
</tr>
</tbody>
</table>

has always been pleasant. In order to make the math relevant and interesting for students, we include active math problems, such as having students calculate the circumference of their automobile tires or compute areas of rooms or buildings at the college. And as a school tradition, the college flagpole has been measured in a variety of ways.

Basic math concepts and vocabulary are covered simultaneously in Math 070, including ample practice with word problems. Students are tested at the end of the week, including a pull-out oral component. While the class takes a written test, students are asked to explain orally to the instructor one of the math problems from the test, which we have found takes about 3 minutes per student. Because our classes are usually small (approximately 15 students), we can select various problems and generally cover one or more problems per student.

In Muscat, the Sultanate of Oman

At SQU, a math course such as the NSCC model was not deemed possible because the existing IEP curriculum is very full. Instead of developing a full course, the SQU Language Center administration authorized the development of self-access, online materials (see Figures 1 and 2). In the engineering and medicine programs, students must complete some or all of the units. Each unit contains a variety of math problems and multiple vocabulary learning tools, including audio segments, in order to facilitate acquisition (Nation, 2001).

Built into the self-access materials are explanations of wrong answers with hints to find correct ones, repeated opportunities to try again, step-by-step
guidance on accurately reading and solving word problems, and tests with aural components.\footnote{This self-access course is designed for use with educational management software programs such as Blackboard or WebCT. To request free copies for noncommercial use, write via post to Bill Huguelet, P.O. Box 43, PC 123, Muscat, OMAN.} Figures 1 and 2 provide samples of these self-access materials. Other topics include: numbers and number listening practice (especially large numbers); basic functions, such as addition, subtraction, multiplication, and division; fractions and decimals; exponents and roots; geometry, such as lines, angles, triangles, circles, and so forth; and word problems. The software provides various features, including

- glossed key words
- definitions through a mouse click
- sound files to hear the pronunciation of the words
- problems requiring students to answer with new vocabulary
- questions, primarily multiple choice and matching
- questions requiring students to listen before answering
Sample Activities for Communicative Practice of Math Language

Most communicative activities can easily be modified to substitute specialized math vocabulary, numbers, and equations to create a fun math vocabulary activity. The following are samples of the types of activities we have developed for our learners on both sites, and for traditional classroom instruction as well as online delivery. The goal of our instructional practices is to give students many opportunities to produce and understand math words, numbers, equations, and so forth. Game-like elements make the activities enjoyable.

Running Dictation

This idea, adapted from Davis and Rinvolucri (1988), has the teacher prepare a set of identical papers containing numbers or equations, which are taped to the wall in different parts of the classroom. Students are divided into pairs, a “runner” and a “writer.” After a start cue, all the runners go to the papers, read silently, and try to remember as much of the number or equation as possible. Make sure to post the paper in a way such that runners cannot stand at the posted paper and shout the information to their scribes. Runners must return to their partner and dictate what they remember, which the writers take down. Runners may need several trips before everything is written down accurately. When all pairs have finished, the teacher elicits the correct version, which goes on the board.
The goal is to perfectly reproduce the paper while practicing oral and reading skills. Variations on this game include

- Different sets of papers are taped up. When a pair finishes the first one, they change roles with the runner becoming the writer and vice versa.

- A short word problem can be used instead of numbers or equations. When the problem has been transcribed, the pair then tries to solve it.

- If the class is too crowded for comfortable movement, or the teacher does not like the confusion of students walking around, the items can be written on the board. All the writers sit with their backs to the board. Runners face the board but dictate from their seats.

**Facts About X (Research and Ask)**

In the previous class, students are assigned a research topic on a theme (planets, animals, countries, properties of nanotubes, etc.) Each student has a different topic, but the theme is the same. For example, if the theme is countries, each student would be assigned a different country to research. Our resources are limited, so we make the best use of such available sources of information as almanacs and various encyclopedias. With Internet access, students can also use sites such as Wikipedia. One SQU class used the CIA World Factbook (n.d.) for demographic data.

As homework, students find and write answers to a set of common questions. For the theme “countries,” students have generated the following questions: How many people live there? How big is it? What is the gross domestic product? How many tons of carbon are produced per capita? In class, then, an empty chart can be put on the board with students copying it into their notebooks. (Copies of blank charts can also be distributed. See Figure 3.) In groups of about five, students ask and answer questions to complete the chart. Active listening and speaking is required.

<table>
<thead>
<tr>
<th>Question</th>
<th>Country 1</th>
<th>Country 2</th>
<th>Country 3</th>
<th>Country 4</th>
<th>Country 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Land area</td>
<td></td>
<td></td>
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<tr>
<td>GDP</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Carbon/capita</td>
<td></td>
<td></td>
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</table>

*Figure 3. Sample Chart*
BINGO! and Tic Tac Toe
These games can be used as a summary activity at the end of class when the board is full or as a stand-alone review. When the board is full of numbers and words, even complex equations from the day’s lesson, students draw a 3 x 3 grid in their notebooks. In each of the nine squares, they write an item from the board. The teacher then calls out the items in a random order, keeping track of what has already been called. Students mark their grids, and when a student has three crosses in a row, he or she shouts, “tic tac toe!” The student must then read back the three items to confirm accuracy and provide speaking practice. As the game continues, the teacher can add challenge by disallowing those three items. BINGO follows a similar principle by having students cross off items as they hear them. When someone has five in a row, they shout BINGO! The student must then correctly read back the five items to be declared a winner. This provides listening recognition practice.

Trivial Review
In Trivial Review, students sit in small groups with a piece of paper and a marker. The teacher calls out (or shows) questions based on recent lessons. Each group negotiates to write an answer without using notes or books. After a specified time elapses, the correct answer is given. Groups then hold up their answers, and if correct, the group gets a point. Items can be simple review or complex story problems. Examples of questions given after a geometry unit include: What is another way to say a 90 degree angle? What is a four-sided figure with only two parallel sides? What is the area of a room that is four meters by five meters? What is the Pythagorean theorem? What is the longest side of a right triangle called? Review such as this reinforces the math concepts and practices using key terms in listening, speaking, and writing.

$20,000 Pyramid (Speedy Math)
This game requires quick responses to simple math problems within a time limit. Each student receives a set of three or four teacher-prepared game cards, each with a list of six to ten simple math calculations. In pairs, one student reads the problems on his or her card to another (but must not show the card). The listener gets one point for each correct computation. The goal is to get through the list within the time limit. After one card has been completed, roles reverse so that the listener becomes the speaker and vice versa. The student with the highest number of points wins the game. Triads or a second pair can act as referees, keeping time and counting points. We have found that this game works best when we keep the problems very simple, focusing on four basic functions, simple fractions, percents, simple exponents, and roots. The first time we play this game with a class, we find it helpful to model it with a volunteer. To save the teacher from writing up all the cards, we have had one group write cards for another group to use, or one
class do a set for another class. Because students also have to supply the correct answers, this provides productive repetition.

**Measure It!**

Everything in a room can be measured and areas and volumes calculated. It is not necessary to have rulers or measuring tapes. It is possible to use any measurement unit, such as one textbook-length or one arm span. In this case, area and volume can be described as square or cubed units. We often go beyond the classroom for this activity with students measuring almost anything, then reporting back to the class. For example, different groups might measure the area of the campus, the amount of classroom space or laboratory space, the area of campus car parks, roads, sidewalks, sports facilities, or even tires or hubcaps on vehicles. A master chart of campus space allocation can then be created and comparisons made, such as the ratio of parking lot area to classroom space. Students may be surprised at the results.

**What Is the Average Student?**

Working in pairs, students are given (or choose) some aspect of student life that can be quantified, such as height, age, number of siblings, and library hours per week spent. Pairs quickly come up with a grammatically correct question to ask in seeking their piece of information. Students then mill around and ask other students in class or in the extended campus community. When the surveys are complete, each pair calculates averages. For example, the average number of siblings could be 2.4. The averages are then compiled on the board or an overhead projector with all students comparing themselves to the average in each category. They determine the number of categories in which they are average or very close. An “average student” can be determined as the one closest to the average in the most categories.

**REFLECTIONS**

Our research and curriculum development has opened up new lines of communication among English and math faculty. In follow-up interviews with math faculty, we found that some professors perceive students’ problems in math as conceptual rather than linguistic. At the same time, other math professors were adamant that the students’ problems were wholly English language related. For the average ESL teacher, math was not a priority. Teachers we interviewed dismissed math with such statements as, “I am hopeless in math.” ESL/EFL teachers and program designers seem to believe—and even express relief—that math is the one course where language is not a factor. Because of this erroneous assumption, the overwhelming majority of teachers interviewed expressed the opinion that poor math concepts—not language—were the cause of students’ difficulties in math courses. Such discord among teachers of both math and English
has hindered efforts to add a math language component to IEP courses on both campuses. Because the self-access course implemented at SQU is currently not a required part of the curriculum, it is difficult to assess its effect on students’ performance in math classes. Indisputable empirical evidence is needed to convince administrators and faculty before changes will be made to the English curriculum. Because we believe that the language of math urgently needs to be addressed in academic ESL/EFL programs, we feel a dedicated ESL math course, such as the one at NSCC, may be the best option when a large number of students are preparing for technical studies. Even when such a course is not possible or appropriate, learning and practicing math language may well be a valuable use of regular classroom time in any English for academic purposes program. This need not be at all boring for students or threatening for teachers, as we demonstrate here. A self-access course such as the one developed at SQU is an alternative, but for full effectiveness, it may be necessary to require it of students.

Math is the basis for almost all science study and thus for all science-related careers, in addition to a multitude of other university pursuits. For this reason, English teachers and academic ESL/EFL programs can no longer ignore the language component in math studies. Educators must provide effective support for integrating math into the language curriculum in order to help our students achieve their academic goals. Research on this at the university level currently is in progress.

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