

Integrating Numeracy and Literacy

By Lesley Lee, PhD and Marilyn Low, PhD

While Marilyn approaches literacy from a content and language perspective where the learning of English must be tied to particular content areas, Lesley has been preoccupied with the language of mathematics or mathematics as a language for a number of years. In the fall of 2004, we were asked by Pacific Resources for Education and Learning (PREL) to commit to a 2-year pilot project called Assistance for the Comprehensive Educational Development (ASCEND) of Mindanao—Lesley as the mathematics specialist and Marilyn as the English specialist. The project involved us in a larger endeavor in the southern Philippines headed by the Save the Children Federation. PREL was to work with a group of about 100 educators from seven of the poorest school districts in the region to improve the teaching and learning of English, mathematics, and science.

School visits and early work with the local educators—not to mention our own backgrounds and beliefs—led us to begin developing an integrated approach to teaching. Thus, our work in the Philippines was the trigger and opportunity to bring together our two fields of expertise and to create an approach to integrating numeracy and literacy where communication and problem solving are emphasized and embedded in everyday contexts. The approach, which we call Pacific Region Integrated Mathematics and English (PRIME), takes hold of what it means to teach meaningful and empowering mathematics and English in ways that take into account the needs and experiences of linguistically and culturally diverse learners. In this article, we provide a theoretical background from each of our perspectives and the principles and practices that grew out of it to become PRIME.

Pacific Contexts

In most Pacific communities, mathematics is taught in English, a second or third language for many students. In some jurisdictions, such as Hawai'i, the medium of instruction is English, the dominant language of the community, and English learners (ELs) are included in mainstream classrooms. In other jurisdictions, such as American Samoa, indigenous languages are the language of home and community, and most, if not all, students are ELs. Furthermore, in some island nations, schooling begins in the local language and transitions to English in grades 3, 4, or 5, depending on the language education policy. For much of the Pacific, school is the primary source for learning English.

The English of mathematics is not, however, everyday English. The language of mathematics, or the mathematics register, is considered a second language for all learners—all students can be categorized as mathematics language learners (MLLs). The school mathematics register, or the language of Western mathematics, typically is not used in Pacific communities outside the school, where it may coexist with or even be eclipsed by indigenous mathematics. Being an EL and a MLL makes learning school mathematics challenging. And classroom teachers fluent in English and the languages their students speak, fluent in the math-

ematics registers of both languages, and confident in teaching mathematics, are hard to find.

Up until this time, attempts to improve mathematics teaching and learning in Pacific schools have focused on mathematical content and pedagogy, including current reforms that aim to embed students' mathematical learning in everyday situations and emphasize mathematical talk. Other interventions work on improving students' competency in English. While both interventions are necessary, the English of mathematics—the very narrow and sometimes unusual use of certain English words in the mathematical register; the new mathematics vocabulary; the symbolism and syntax of mathematics; the language of hypothesizing, conjecturing, generalizing, and proving—is not typically addressed. While the second language field has developed and implemented language and content approaches across disciplines with considerable success in Canada and the continental U.S., and the language of math has been explored in the field of mathematics and education research, few have taken an interdisciplinary perspective.

Why Integration?

Focusing on content alone in the content classroom makes language the invisible curriculum. Immersion programs have a double goal of both language and content learning. Key to language and content approaches is a focus on relating form (grammar) and function (meaning).

In language and content classrooms, language is used in the service of other learning, with planned integrations of content and language that promote culturally contextualized teaching practices. Language and content teachers are concerned with the functionality of language and the need to take advantage of the learners' communicative environment. They use a number of pedagogical strategies and techniques, such as various student grouping strategies; active participation in concrete task-based or experiential, inquiry-based learning; graphic organizers; and a whole language approach.

In these classrooms, teachers are aware of the language they use and deliberately create opportunities for students to hear and use it in the construction of their own

content knowledge—language becomes a routine aspect of lesson planning and teaching and learning in the content classroom. The dynamic nature of language and content provides students an opportunity to learn what is most relevant at that time (language and/or content), while being fully engaged in learning activities and challenged at an appropriate conceptual level.

Mathematics and Language

Many mathematicians and mathematics educators claim mathematics is a language—with its forms, functions, and meanings, and with its highly developed syntax and rather narrow semantics. The language view has served mathematics educators well, since it has allowed the community to become more aware of the nature of the mathematical language—or mathematics register, as it is generally referred to—and the complexities of teaching and learning it.

Pimm, a mathematics educator, devoted a large part of his 1989 book, *Speaking Mathematically* (Routledge), to an analysis of the mathematics register. Some important characteristics of the mathematics register are:

- Specialized words rarely occurring outside mathematics (such as *multiplicand*, *parallelogram*, *asymptote*, *isosceles*, *hypotenuse*).
- Words taken from everyday English but given restricted or new meaning (such as *diagonal*, *straight*, *equality*, *face*, *degree*, *relation*, *power*).
- Phrases or ways of putting English words together to produce new meaning (such as *simultaneous equa-*

tions, *absolute value*, *right angled triangle*, *square root*).

- Modes of arguing and proving (reductio ad absurdum, induction, deduction, use of counter examples).
- Particular sentence constructions characterized by greater use of the passive voice (a line is drawn to bisect . . .), gerunds (*addend*, *integrand*, *multiplicand*), and a range of imperative forms (*let*, *suppose*, *define*, *consider*).

Written mathematics has additional peculiarities; it is not just spoken mathematics written down in words. By middle school, students in mathematics are expected to use a highly symbolic and succinct notational form, which includes the use of letters of the alphabet as nonalphabetical symbols; the use of Greek letters as fixed constants (π for the fixed ratio of a circle's circumference to its diameter), variables ($3\alpha + 2\beta$), or abbreviations for operations (Σn for the sum of the numbers from 1 to n); the positioning of numbers and letters as superscripts (sometimes to indicate powers or exponents) or subscripts; and a whole collection of symbols for operations ($=$, $+$, \div) and relationships (\geq , \approx , \in).

Pimm offers that, "Most math classes are conducted in a mixture of the registers of ordinary English and mathematical English, and failure to distinguish between these two can result in incongruous errors and breakdowns in communication" (p. 88). Pimm claims that teachers are often not aware of moving from one register to another and do not appreciate the pitfalls for the learner.



Photo by Liane Singh

In 1994, the National Council of Teachers of Mathematics (NCTM) published a position statement on language minority students which essentially says that “cultural background and language must not be a barrier” to the study of a full curriculum in mathematics. The NCTM (1989) goals for mathematical literacy are that students learn to value mathematics, become confident in their ability to do mathematics, become mathematical problem solvers, learn to communicate mathematically, and learn to reason mathematically.

What Numeracy and Literacy Integration Looks Like

We use PRIME as an example of a language-focused approach to improve the learning and teaching of mathematics. It is based on four key principles. We then provide an outline of an integrated lesson that puts these principles into practice.

PRIME Principles

1. The mathematics classroom provides a comfortable/risk-taking learning environment. According to the 1991 NCTM *Professional Standards for Teaching Mathematics*, “In order to facilitate learning by all students, teachers must also be perceptive and skillful in analyzing the culture of the classroom, looking out for patterns of inequality, dominance, and low expectations that are the primary causes of non participation by many students.” Certain rules of classroom behavior involving active participation, listening, and mutual respect need to be established and sustained. If learners feel supported and secure, they will be willing to risk using their language resources to make mathematical meaning; if they feel comfortable, they will risk sharing with peers and the teacher their ideas about their mathematical work.
2. English is used in the service of learning mathematics, with planned integration of mathematics content and language. In the mathematics classroom, the focus is on the mathematics and the mathematical tasks the students are engaged in. In the course of these activities, students need to formulate questions, make conjectures, present solutions, and write for themselves or publicly. Needed words from the mathematical register or the school English register are picked up from peers, the teacher, and written and electronic material. In other words, they learn the language of mathematics and of the mathematics classroom because they are immersed and engaged in a mathematical community of inquiry.
3. There are planned opportunities for meaningful, comprehensible interaction in the mathematics classroom (e.g., between peers, between students and teacher). The peer group is a powerful resource to the learner, providing a wide range of models of language use, and the need to communicate offers the learner a real motivation to use language in the mathematics class-

room. According to the NCTM *Professional Standards for Teaching Mathematics*, “Students must talk, with one another as well as in response to the teacher. When the teacher talks most, the flow of ideas and knowledge is primarily from teacher to student. When students make public conjectures and reason with others about mathematics, ideas and knowledge are developed collaboratively, revealing mathematics as constructed by human beings within an intellectual community.” A classroom that uses a wide variety of peer interaction from whole-group to small-group organizations allows for the widest range of mathematical discourse.

4. Learners have opportunities to be mathematics “problem solvers” rather than “information receivers.” Students need to have opportunities to be “problem posers” as well. The central activity of problem solving and problem posing in the mathematical community is the cornerstone of the NCTM’s *Principles and Standards for School Mathematics* (2000). Besides recognizing the central role of problem solving (routine, nonroutine, open-ended) in all students’ learning, the NCTM recognizes its crucial role in the development of mathematics discourse. “The teacher of mathematics should promote classroom discourse in which students . . . use a variety of tools to reason, make connections, solve problems and communicate; initiate problems and questions; make conjectures and present solutions; explore examples and counterexamples to investigate a conjecture; try to convince themselves and one another of the validity of particular representations, solutions, conjectures, and answers . . .” (NCTM, *Professional Standards for Teaching Mathematics*, 1991).

Principles Into Practice

We end this article with an outline of a PRIME lesson, offering an example of a classroom activity that promotes integrated numeracy and literacy learning and is culturally contextualized. As part of a larger unit on comparing quantities, students in this lesson are learning to compare the areas of different types of locally found leaves in preparation for covering/protecting young plantings in a taro patch. Language resources that teachers model and students apply in carrying out the task are highlighted. Teachers use oral strategies to develop students’ fluency in their use of mathematical language and English. Such fluency requires frequent and deliberate uses of language in mathematics activities. Working orally in groups on problem-solving tasks, such as the one on comparing area, invites students to think and talk like mathematicians. Extensions of this activity may involve writing and/or visual literacy, where students write and/or illustrate the mathematics they are learning.

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Task: Compare the areas of these two leaves.

This comparison can be set in a context of choosing what type of leaves to use to cover/protect plantings in a taro patch (where the leaf that covers the biggest area is preferred).



Photo by Lesley Lee

Is the area (B) of the broad leaf greater than, less than, or equal to the area (T) of the thin leaf?

or

Which of the following is true?

$B > T$ $B < T$ $B = T$

Are there any conjectures?

How can we test our conjectures?

Here is a list of available materials to use in our investigation:

1. Scissors and glue
2. String and 30 cm. wood ruler
3. Plastic cubic centimeters
4. Pennies or one cent coins
5. Triangle and rhombus pieces from a set of pattern blocks
6. Square grid paper

Six teams form around the six materials and work on accomplishing the comparison task (testing conjectures, answering the question).

A plenary session follows where each team presents its work and answer to the question. Because the leaves are very close in area, teams may vary on their answers. A discussion follows on the advantages and disadvantages of the different materials and which team's answer might inspire more confidence.

The materials used by the second team (string and ruler) give rise to some interesting discussions if the team used the string to compare perimeters. The relationship between perimeter and area can become the subject of another lesson. Question: If the perimeter of one leaf is bigger than the other, is its area bigger too?

Teacher draws attention to “mathematics talk” by modeling and encouraging students to use such talk as s/he pushes them to explain their thinking and how they figured out the answer to the question.

Comparison structures and symbols:

is greater than ($>$)

is less than ($<$)

is equal to ($=$)

Words and their symbols are written on the board or chart paper and students are encouraged to use them. Other comparative forms using “er” are modeled:

B is larger than T

T is smaller than B

Conjecturing requires students to make an “informed guess.” In this task, the conjectures describe. For example, I think B is larger than T. T is smaller than B. They have the same area.

Note the use of “to be” and “to have” verb forms. Present tense is used in conjectures of this type. In other tasks, students might need to use an “if...then” form of conjecture.

Testing conjectures requires the use of a variety of imperatives:

Cover the leaf with these coins.

Count them.

Vocabulary may include, for example, mathematics words in English that have no equivalent in the local language or that translate in two or more ways.

Collaborating to complete the task requires students to use language to:

- Make polite requests (Please pass . . .).
- Take and give turns (Tero, what do you think?).
- Clarify (Can you please repeat?).
- Questioning (What do we do with the gaps between pennies?).

