UNIT 9

MATHEMATICAL SKILLS AND HABITS

OVERVIEW FOR TEACHERS

Unit Outline

Introduction:

In addition to the text, the explanations and the diagrams, the thousands upon thousands of extremely complicated computations for the tables drained all his strength and time. This was long before any such thing as a mechanical calculator, so every formula had to be laboriously written on the slate. Since he [Nathaniel Bowditch] was determined that above all, his book should be accurate, he worked each set of figures three times. (**To Steer by the Stars**, p. 166)

Nathaniel Bowditch was a natural mathematician–he found joy in counting, measuring, estimating, calculating, thinking logically, and looking for patterns. Nat also paid attention to details. Early in his life, he developed good habits - counting carefully, measuring accurately, and calculating over and over again to insure accurate answers. His good habits saved many lives, as well. The accuracy of Bowditch's *New American Practical Navigator* allowed ships to navigate with confidence; the mathematical tables that their lives

A few mistakes can lead to many other errors. Bowditch examined and recalculated the commonly used navigation tables of the early 1800's and discovered over 8000 mathematical errors! Scientists and mathematicians know that simply one or two errors in computation or measurement can lead to drastic miscalculations and conclusions. In the following unit, students will discover how one miscalculation in a checkbook entry can cause all the other entries to be wrong until the error is corrected. Students will apply their understanding of miscalculations to potential navigation errors. The mismeasurement of an angle by only a few degrees can lead sailors hundreds of miles off course, landing them in another country, perhaps even another continent!

Bowditch's mathematical skills made him invaluable as a supercargo on a ship:

Soon his head was filled with numbers, translating everything about the cargo into columns of figures, into addition, subtraction, multiplication, and division. The numbers flew through his head in a swirling tide of calculations in which he computed weights, values, units of money, money exchange of foreign countries, duties and many other things.
(**To Steer by the Stars**, p. 23)

Students will practice their own computational skills as they convert percents to decimals or fractions. They will solve problems involving weight conversions, requiring skill in determining proportions. Finally, students will calculate duties, taxes and rates of foreign exchange, skills essential to the success of any Salem merchant ship.

Objectives:

- Students will investigate and discuss jobs that require math skills.
- Students will examine and correct a budget problem and a checkbook problem.
- Students will measure and compare distances between lines when the angle is varied.

Skills:

- Students will be able to practice their skills in counting, measuring, esti mating, calculating, thinking logically, looking for patterns.
- Students will know how to practice good mathematical habits in solving the above problems as they:

    1. Pay attention to details

2. count, measure, calculate carefully, and

3. check their work.

- Students will be able to use a ruler and a protractor to construct and mea sure angles.
- Students will know how to use proportions to solve problems.
- Students will understand how to use deductive reasoning as they apply general rules to specific examples.
- Students will be able to convert percents to decimals and fractions in order to compute duties (taxes).

Vocabulary:

- surveyor
- duty
- supercargo
- percent
- bookkeeper
- accuracy
- actuary
- approximate

Frameworks connections:

Mathematics:

Strand 1: Number and Number Relationships

Standard 1.6 (p. 40)
- Apply rations, proportions, and percents.
- Represent and use equivalent forms of numbers, including fractions, decimals . d percents.

Strand 2: Computation and Estimation

Standard 1.3 (p.42)
- Compute with whole numbers, fractions, decimals.
- Develop, analyze, and explain procedures for computing, estimating, and proportions to solve problems.

Strand 3 : Measurement

Standard 3.4 (p. 76)
- Select appropriate units and tools to measure the degree of accuracy required in a particular situation.
- Describe the concept of weights and other derived and indirect measurements.

Strand 4 : Statistics

Standard 4.2 (p. 90)

- Collect, organize, and describe data systematically.
- Construct, read and interpret tables, charts, and graphs.

Unit 9 Lesson Plans

Lesson 1: The Importance of Accuracy

Objectives:

- Students will name jobs and careers that require mathematical skills (counting, measuring, estimating, calculating, thinking logically, looking for patterns).
- Students will practice good mathematical habits:
- Pay attention to details.
- Count, measure, calculate carefully.
- Check their work.
- Students will discover that one or two mistakes in calculation or measurement can lead to many more, and that a small error in measurement can lead to huge miscalculations.

Skills:

- Students will be able to practice:
  - counting
  - measuring
  - estimating
  - calculating
  - thinking logically
  - looking for patterns
- Students will learn how to practice:
  - paying attention to details
  - counting, measuring, calculating carefully
  - checking their work
  - constructing and measuring angles and angular distances
- Students will understand how to use proportions and deductive reasoning.

Vocabulary:

- surveyor
- bookkeeper
- supercargo
- actuary
- accuracy

Materials:

- small plastic protractors, rulers, pencils
- big wooden protractor for chalkboard
- chalk, yardstick, masking tape
- world (political) maps
- Optional: rolling tape measure, masking tape

Procedure:

1. Read the story-problem about the trip to the mall, compare the results of the problem done correctly with the results of the problem done with several miscalculations.

2. Track entries on a page from a mock checkbook. On the first entry, ask the students to add when they should subtract, noting that not only is the first answer incorrect, but the rest of the answers are wrong as well.

3. Construct an angle of 9 degrees with sides of 3 inches. Students will measure the distance between the sides of the angles at the tips of the rays (1/2 inch). Extend the sides of the angles to 6 inches and measure the distance at the tips of the rays (1 inch).

4. A student should go to the chalkboard and use a large wooden protractor to construct an angle of 9^{o} with sides of 18 inches. Measure the distance between the sides (3 inches). Is this the expected answer? (Yes.) What if the rays are extended to 24 inches? Discover the general rule that applies to this problem through deductive reasoning.

5. Take the students to a large area such as the gym, cafeteria or schoolyard. Two students should start from the same spot (marked by an 'X' in masking tape), but vary their course by 5 degrees. Walk 20 feet in a straight line. Measure the distance between them when they stop (kinesthetic learning).

6. Using a series of proportions, students can determine the distance between the rays after 12 inches or 1 foot (2 inches), after 60 feet (10 feet), after 5280 feet or 1 mile (880 feet), after 3000 miles (500 miles).

7. Problem: A ship from Salem, Massachusetts plotted a course toward Spain. The navigator made a mistake and calculated a course 9^{o} SE of the correct bearing. Where will the ship land?

Handouts:

- Worksheet "Accuracy Is Important" (2pp.)

Accuracy is Important Answers

Nathaniel Bowditch (1773-1838) had many jobs in his lifetime: surveyor, bookkeeper, supercargo, actuary. These jobs require good math skills, such as counting, measuring, estimating, calculating, thinking logically, looking for patterns. Can you think of other careers that require math skills? What really made him a good mathematician, however, were some of his habits. He paid attention to details, he was very careful when he counted, measured or calculated and he checked his work! Bowditch knew accuracy was important.

In writing a book on celestial navigation, Nat worked carefully---sailors' lives depended on his careful calculations!

In addition to the text, the explanations and the diagrams, the thousands upon thousands of extremely complicated computations for the tables drained all his strength and time. This was long before any such thing as a mechanical calculator, so every formula had to be made laboriously on the slate. Since he was determined that above all, his book should be accurate, he worked each set of figures three times. (***To Steer by the Stars***, p. 166)

As a young man, Bowditch had studied the navigational tables that sailors used. He spotted some errors and corrected them. By the time he had finished the book of tables, he had found over 8000 errors! How could such a thing happen? A few mistakes can lead to many other mistakes, in this case, thousands of mistakes. In fact, just one or two errors in calculation can lead to many more errors. We'll see how that is so.

Example 1: Let's say you and your friends were going to spend an afternoon at the mall. You have $40 to spend and you figure you'll be able to buy some CD's, have pizza and a soda, then see a movie. First, you purchase 3 CD's on sale for $9.99 and miscalculate that the total will be $27 instead of? ($29.97) You subtract 27 from 40 and get $13 left, but how much do you really have? ($10.03) your share of the pizza and soda comes to $6, which you subtract from the $13 you think you have, and you miscalculate again, and now think you have $9 left---just enough for the movie. How much do you really have? ($4.03) Guess who's not going to the movies?

	Your Answer	Right Answer
start with	$40.00	$40.00
3 CD's @ $9.99	-$27.00	$29.97
how much left	$13.00	$10.03
pizza and soda	- 6.00	- 6.00
how much left	$ 9.00	$ 4.03

Example 2: Many people have a checking account. Deposits (or credits) add money to the account. When a person writes a check (or debit) it subtracts money from the account. Here is an example where a person made a computational error just once, but it affected her entries (answers) for the next eight transactions. (Teachers: Have students start out with a balance of $1000.00. Then have them 'write' out a check for $240.00 and add it their balance instead of subtracting it. As a class, enter several more transactions, and have them add deposits and deduct check amounts correctly. Have them note their balance is still 'off', all because of one mistake in the beginning.)

Date	Check No.	TRANSACTION	Credits (+)	Debits (-)

You've seen how a little computation error or carelessness can get you into trouble. One measurement that is just a little bit off can also lead to a BIG mistake!

Example 3: Teacher: Using a big wooden protractor, draw on the chalkboard a 30° and a 32° angle from the same vertex. Make the rays of the angle 4" long. Have a student come up to the board and measure the distance between the tips of the angles. (1/4") Write that result on the board. Now extend the rays to 12" (= 1 ft.) each, and have another student measure that difference. (3/4") Write that result on the board. What if we make the rays 4' long? (Difference is now 3"long.) 16' long? (off by 12"=1') Now ask students what would happen if the sides of the angles were extended for a mile. Use a simple proportion to figure out how far off you'd be by then. (330') How far off would you beafter 3200 miles? Encourage them to use simplification methods to do this Calculation. (200 miles! That could put you in another country or even on another continent!)

Avoiding Errors

If you really want to excel in math, you must practice the habits which Nathaniel Bowditch practiced. You must:

- pay attention to details
- count, measure, and calculate carefully
- check your work

There are ways to make your math life easier.

ACCURACY IS IMPORTANT

Nathaniel Bowditch (1773-1838) had many jobs in his lifetime: surveyor, bookkeeper, supercargo, actuary. These jobs require good math skills, such as counting, measuring, estimating, calculating, thinking logically, looking for patterns. Can you think of other careers that require math skills? What really made him a good mathematician, however, were some of his habits. He paid attention to details, he was very careful when he counted, measured or calculated and he checked his work! Bowditch knew accuracy was important.

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	Your Answer	Right Answer
start with	$40.00	$40.00
3 CD's @ $9.99	-$27.00	
how much left	$13.00	
pizza and soda	- 6.00	
how much left	$ 9.00	

Example 2: Many people have a checking account. Deposits (or credits) add money to the account. When a person writes a check (or debit) it subtracts money from the account. Here is an example where a person made a computational error just once, but it affected her entries (answers) for the next eight transactions. (Teachers: Have students start out with a balance of $1000.00. Then have them 'write' out a check for $240.00 and add it their balance instead of subtracting it. As a class, enter several more transactions, and have them add deposits and deduct check amounts correctly. Have them note their balance is still 'off', all because of one mistake in the beginning.)

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- check your work

There are ways to make your math life easier.

Lesson 2: Paying Duty

Objectives:

- Students will calculate the duty, or tax, on the value of goods.

Skills:

- Students will be able to read and use information from tables to solve problems.
- Students will know how to change percents to equivalent decimals.
- Students will understand how to change percents to equivalent fractions.
- Students will learn how to find the percent of a quantity by multiplying the quantity by a fractional or decimal equivalent of the percent.

Vocabulary:

- duty
- percent

Materials:

Procedure:

1. Distribute worksheet "Paying Duty".
2. Show students how to convert percents to decimals. (see worksheet.)
3. Show students how to convert percents to fractions. (see work sheet.)
4. Present the challenge problem at the end of worksheet. Determine the various duties on ten items. Add the duties to find the total duty for the cargo. This activity can be worked in small groups of three or four students.

Handout:

Worksheet "Paying Duty" (2pp.)

Paying Duty

If a merchant ship returned safely to Salem after its voyages to far ports, it would be laden with exotic goods from all over the world. Wine, citrus and dried fruits from Spain, cocoa and ivory from Africa, cottons from India, coffee from Arabia, cinnamon, cloves and black pepper from the East Indies, porcelain, tea and silk from China filled Salem warehouses. This meant big profits for the ship owner, but first, a duty had to be paid. A duty is a type of tax paid on goods brought into a port. The collector for the port would assess (find the value of) the goods, then he would collect a certain percent of the value as duty.

When working with percents, you need to change the percent to an equivalent decimal or fraction. Converting a percent to a decimal is very simple: you simply drop the % sign and move the decimal point two places to the left. (If you do not see a decimal point, it is assumed to be at the end of the number.) For single digit numbers, write a '0' before the number before you drop the % sign and move the decimal point two places to the left. Here are some examples:

35% = .35 4% = 04% = .04 125% =1.25 37.5% = .375

Percents can easily be changed to a fraction when you know that percent mean "out of a hundred". For example, 17% = 17/100. 4% = 4/100 = 1/25. Remember always to simplify your work by reducing fractions to lowest terms.

Use the table below to figure out the problems on your worksheet. Here are a couple of examples:

Example 1: Find the duty on $2500 worth of silk.

Solution: From the chart, the duty on silk is 20%. 20% = 20/100 = 1/5.

1/5 of $2500 = $500. ("of" with fractions mean "multiply")

Example 2: Find the duty on iron valued at $600.

Solution: From the chart, the duty on iron is 5%. 5% = .05.

.05 x $600 = $30.

5%	10%	12%	20%
iron	porcelain	cinnamon	silk
zinc	salt	cloves	ivory
lemons	coffee	nutmeg	jade
limes	tea	ginger	gold dust
oranges	cocoa	black pepper	
dates	sugar		
figs			

1. Find the duty on $3240 worth of porcelain. (Use the fraction equivalent.)

2. Find the duty on $4800 worth of cinnamon. (Use the decimal equivalent.)

3. Find the duty on $280 worth of oranges. (Use the fraction equivalent.)

4. Find the duty on $650 worth of salt. (Use the decimal equivalent.)

5. Find the duty on $125 worth of ivory. (Use the fraction equivalent.)

6. Find the duty on $2460 worth of zinc. (Use the decimal equivalent.)

7. Find the duty on $1500 worth of black pepper. (Use the fraction equivalent.)

8. Find the duty on $2250 worth of silk. (Use the decimal equivalent.)

CHALLENGE:

A ship returns to Salem with cargo that has been assessed as follows:

$3660	iron
$760	lemons
$1080	limes
$4880	coffee
$2970	tea
$3450	sugar
$2000	cinnamon
$2400	cloves
$3200	black pepper
$1555	silk

What is the total amount he may pay in duties?

Paying Duty Answers

1. *$324*
2. *$576*
3. *$14*
4. *$65*
5. *$25*
6. *$123*
7. *$180*
8. *$450*

CHALLENGE:

$2628

UNIT 9 STUDENT HANDOUT

PAYING DUTY

If a merchant ship returned safely to Salem after its voyages to far ports, it would be laden with exotic goods from all over the world. Wine, citrus and dried fruits from Spain, cocoa and ivory from Africa, cottons from India, coffee from Arabia, cinnamon, cloves and black pepper from the East Indies, porcelain, tea and silk from China filled Salem warehouses. This meant big profits for the ship owner, but first, a duty had to be paid. A duty is a type of tax paid on goods brought into a port. The collector for the port would assess (find the value of) the goods, then he would collect a certain percent of the value as duty.

When working with percents, you need to change the percent to an equivalent decimal or fraction. Converting a percent to a decimal is very simple: you simply drop the % sign and move the decimal point two places to the left. (If you do not see a decimal point, it is assumed to be at the end of the number.) For single digit numbers, write a '0' before the number before you drop the % sign and move the decimal point two places to the left. Here are some examples:

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Use the table below to figure out the problems on your worksheet. Here are a couple of examples:

Example 1: Find the duty on $2500 worth of silk.

Solution: From the chart, the duty on silk is 20%. 20% = 20/100 = 1/5.

1/5 of $2500 = ("of" with fractions mean "multiply")

Example 2: Find the duty on iron valued at $600.

Solution: From the chart, the duty on iron is 5%. 5% = .05.

.05 x $600 =

5%	10%	12%	20%
iron	porcelain	cinnamon	silk
zinc	salt	cloves	ivory
lemons	coffee	nutmeg	jade
limes	tea	ginger	gold dust
oranges	cocoa	black pepper	
dates	sugar		
figs			

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6. Find the duty on $2460 worth of zinc. (Use the decimal equivalent.)

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CHALLENGE:

A ship returns to Salem with cargo that has been assessed as follows:

$3660	iron
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$1080	limes
$4880	coffee
$2970	tea
$3450	sugar
$2000	cinnamon
$2400	cloves
$3200	black pepper
$1555	silk

What is the total amount he may pay in duties?

Lesson 3: Trading and Fair Exchange

Objectives:

- Students will determine a fair exchange for varying amounts of various goods.

Skills:

- Students will learn to set up proportions (a good problem-solving technique) to find an equivalent ratio given a known rate of exchange.
- Students will be able to cross-multiply to solve the proportions.
- Students will understand, read, use information from a table and construct tables to solve problems.

Vocabulary:

- Proportion

Materials:

Procedure:

1. Distribute worksheet "Trading and Fair Exchange".
2. Introduce proportions: proportions are two equivalent ratios.
3. Use the table on the worksheet to set up proportions.
4. Students cross-multiply to solve the proportions.
5. Challenge Problem: In small teams of three or four students, brainstorm how to solve the problem. Let the quantities in the tables represent units. For example, 120 lbs. of iron equals 1 unit of iron, 24 lbs. of cinnamon equals 1 unit of cinnamon, and so on. 5 units of iron could be traded for 5 units of cinnamon (120 lbs.) or 5 units of cloves (100 lbs.) 4 units of cinnamon (96 lbs.) plus 1 unit of cloves (20 lbs.) or 3 units of cinnamon plus 2 units of cloves (40 lbs.), and so on.

Trading and Fair Exchange

Let's say anything in Column A of the chart below could be exchanged for anything in Column B. For example, 24 lbs. of cinnamon could be traded for 120 lbs. of iron or 50 barrels of flour or 150 bales of cotton, etc. The 120 lbs. of iron, 50 barrels of flour or 150 bales of cotton could also be traded for 20 lbs. of cloves or 36 lbs. of coffee, and so on. Use the information from the table and set up proportions to solve the problems below. (Examples are hypothetical.)

A	B
24 lbs. of cinnamon	120 lbs. iron
20 lbs. of cloves	200 pcs. of wooden ware
45 lbs. of black pepper	50 barrels of flour
36 lbs. of coffee	150 bales of cotton
32 lbs of sugar	54 sacks of corn
12 lbs. of tea	48 sacks of rice
100 lbs. of salt	72 bundles of tobacco
18 bolts of silk	60 barrels of dried fish

Example: How many lbs. of cloves could you trade for 60 bales of cotton?

Solution: Set up a proportion: $\frac{\text{150 bales cotton}}{\text{60 bales cotton}} = \frac{\text{20 lbs. cloves}}{\text{Y}}$

Cross-product: 60 x 20 = 150Y
1200 = 150Y
Y = 8, answer
8 lbs. of cloves can be traded for 60 bales of cotton

Here are some for you try:

1. How many bolts of silk could you trade for 500 bundles of tobacco?
2. How many sacks of corn would you need to trade for 105 lbs. of black pepper?
3. How many lbs. of coffee could you trade for 225 barrels of dried fish?
4. How many pounds of iron would you need to trade for 72 lbs. of sugar?

5. How many pounds of cinnamon could you trade for 84 sacks of rice?

6. How many barrels of flour would you need to trade for 42 lbs. of tea?

CHALLENGE: Work in groups of three or four to solve the next two problems. Each problem has several answers. (Hint: making a table would be a could problem-solving strategy here.)

A. How much salt and pepper could be traded for 600 lbs. of iron?

B. How much much corn and rice would be a fair exchange for 72 lbs. of cinnamon and 80 lbs. of cloves?

Trading and Fair Exchange Answers

1. 125 bolts of silk

2. 126 sacks of corn

3. 135 lbs. of coffee

4. 270 lbs. of iron

5. 42 lbs. of cinnamon

6. 175 barrels of flour

CHALLENGE:

A. Solution: Think of 120 lbs. of iron as 1 unit of iron (I), 100 lbs. of salt as 1 unit of salt (S), and 45 lbs. of pepper as 1 unit of pepper (P). The units are all equivalent since

120 lbs. of iron is worth 100 lbs. of salt or 45 lbs. of pepper. 600 divided by 120 is 5,

so we need 5 units of salt and pepper to equal 5 units of iron. We could have 1 unit of

salt plus 4 units of pepper, 2 units of salt and 3 units of pepper, 3 of salt and 2 of

pepper, or 4 of salt and 1 of pepper.

salt	iron	pepper
1@ 100 lbs=100 lbs. S=120 lbs. I	120 + 480 = 600 lbs.	4@ 45 lbs=180 lbs. P=480 lbs. I
2@ 100 lbs=200 lbs. S=240 lbs. I	240 + 360 = 600 lbs.	3@ 45 lbs=135 lbs. P=360 lbs. I
3@ 100 lbs=300 lbs. S=360 lbs. I	360 + 240 = 600 lbs.	2@ 45 lbs= 90 lbs. P=240 lbs. I
4@ 100 lbs=400 lbs. S=480 lbs. I	480 + 120 = 600 lbs.	1@ 45 lbs= 45 lbs. P=120 lbs. I

B. This is similar to the problem above, but a little more complex. 72 lbs. of cinnamon would be equal to 3 units, and 80 lbs. of cloves would be equal to 4 units. So we need combinations of corn and rice that equal 7 units. The units combinations are listed below. It is up to the reader to compute the various amounts (e.g., 2 corn units = 108 sacks corn + 5 rice units = 240 sacks rice).

corn units	rice units	cinnamon units	clove units
1	6	3	4
2	5	3	4
3	4	3	4
4	3	3	4
5	2	3	4
6	1	3	4

UNIT 9 STUDENT HANDOUT

TRADING AND FAIR EXCHANGE

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Cross-product: $60 \times 20 = 150Y$

$1200 = 150Y$

$Y =$

lbs. of cloves can [illegible] traded for 60 bales of cotton

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