THE

ANTARCTICA PROJECT

A MIDDLE-SCHOOL MATHEMATICS UNIT

MMAP

The Antarctica Project is a middle-school multi-disciplinary mathematics unit written by the Middle-school Mathematics through Applications Project (MMAP). Teachers from the San Francisco Bay Area and researchers from the Institute for Research on Learning (IRL) and Stanford University have developed this unit under the auspices of a grant from the National Science Foundation.

CONTRIBUTING STAFF:

These units were originally developed by the MMAP team, including MMAP staff and teachers from California, Oregon, Michigan, Alaska and New York, supported in large part by a grant from the National Science Foundation.

The unit was revised by Big Learning, Inc. in 2007 with support from the CK12 Foundation.

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Overview

The Antarctica Project teaches middle school students to use functions to solve a complex, real-world problem. The unit also includes review of measurement, scale, area, perimeter, and surface area concepts, as well as some computation practice.

Students take on the role of architects designing a new Antarctic research station to meet the needs of the scientists who will live and work in it. They are given a requirements list that includes designing living quarters and workspace for four scientists, while minimizing the cost to build the station and heat it.

Each activity of the two-week unit brings new math and design challenges. Students learn new concepts about functions and gain flexibility applying previously covered material. Every concept is used authentically, as real architects would use mathematics in their work.

Unit Summary

Activity 1 – 2: Create Designs: Students design a research station that meets the work and living needs of scientists to be built in Antarctica and draw it to scale.

Activity 3: Design Review Assessment: Students present their designs to the class to check the scale and proportion of their designs.

Activity 4-5: Revise designs, reduce perimeter. Students order prefab wall panels for their designs and reshape their designs to use fewer panels without losing floor area.

Activity 6: Revise designs to reduce surface area. To reduce the amount of heat lost through the structure, students compare one-story and two-story designs.

Activity 7: Build 3-D models: Students build 3-D models of their final design.

Activity 8: Choose insulation: Students solve a 2-variable optimization problem as they choose the insulation level that will optimize the cost to build the station and heat it for 20 years.

Activity 9: Final reports: Students summarize the mathematical features of their designs. They also create journals about their design and math work through the project.

Activity 10: Unit assessment.

Mathematics Content

Activity 1-6	Metric measurement, scale drawings. Functions with area, perimeter, and surface area.
Activity	Scale modeling in three dimensions.

7:	
Activity 8	Writing functions to solve real-world problems.
Activity 9	Review and Assessment

About The Antarctica Project: Learning Middle-School Mathematics Through Applications

Antarctica, like all units developed by the Middle-School Mathematics through Applications Project (MMAP), is based on new thinking about mathematical applications. Traditionally, applications were something that came at the end of the chapter, in the form of a few of those dreaded word problems, where students practiced the algorithm they'd just learned. That is not the kind of application you will find herein. Instead, each application is a "slice" of the real world that has potential for engaging young people in mathematics, rather than a list of mathematical skills to be learned. Students work within a design thinking scenario with a problem that encourages them to create and analyze designs to meet human needs. These design thinking scenarios provide plenty of opportunities for mathematics to be used and learned along the way.

How do students better learn math through this kind of application? Real-world design scenarios provide both reasons and resources for learning mathematics. The *resources* are the real-world designs students are making. They can constantly check out their mathematical insights in terms of their design and their knowledge about the world. For example, in *Antarctica,* as students learn about scale, they can constantly refer back to the research station they are designing to see whether their mathematical learning about scale makes sense in their design. The *reason* for learning mathematics comes from students' intense engagement in the design thinking process. Middle schoolers find designing for human needs compelling: such units appeal to their senses of humanity, their sense of agency, and their imagination about their adult futures. For example, in *Antarctica,* students imagine themselves as architects who design a fully-functioning research station for scientists. This is a playful design thinking scenario is based on real-world adult work.

What does this learning process look like in the classroom? In *Antarctica,* as students assume the role of architects, each student plays a role in a group, and each group in the class-wide activity. As students work through the design challenges and math activities, mathematical problems emerge, and it becomes *functionally* necessary to learn and do the math to create the design solutions encountered throughout the unit.

How do these units prepare students for future study and work? MMAP is committed to preparing a diverse population for the 21” century through exceeding national math standards. The curriculum materials in *Antarctica* make math accessible, exciting, and successful for middle school students. Through working on the complex real-world design problems in the unit, middle schoolers find more enthusiasm for math and for 21st century skills—which can, in turn, carry over into future study, particularly for girls and students of color who traditionally have been under-represented in mathematical and technological fields.

How to Use this Unit

This unit is organized by activity. The materials for each activity include the instructions, assessments, handouts, and answer sheets you need for that activity. Refer to the Detailed Unit Map to see what materials and resources you need for the whole unit.

Memos: Students play the role of designers and architects in a large design firm. Each new math challenge is introduced to the students by a memo from the chief designer of the firm.

Modular activity structure: The unit has a modular design that you can customize. You can:

- Stop anywhere and the unit will still feel valuable and complete.
- Add your own activities and challenges to create a better match for your area's curriculum standards and assessments.
- Leave out activities you think are too hard or too easy for your students. Once students create their initial scale drawing, most of the other days do not depend on previous days.

Differentiation Support: The unit objectives correspond to **typical 7th grade scope and sequence**. However, the activities are designed so that **below-grade-level students** can make real contributions to their group while catching up on skill work. In addition, most activities offer **Advanced Study Ideas** so that advanced students can also make real contributions, but at a higher level. This raises the level of the unit for the class as a whole without singling out advanced students for extra work.

Collaboration plus individual work: Collaborating with others is both a crucial 21st-Century work skill and a characteristic of complex architectural design in the real world. Further, group discussion enhances math learning for all students. Within this group context, however, the unit is designed to make it easy for you to assess and ensure each student's understanding of the underlying math concepts.

Grading: The unit includes two quizzes, a final report, and a unit test. In addition, students earn points for group assignments, individual assignments, and homework completion. You can assign a unit grade based on the percentage of the total points students earn during the unit. See Items for your Grade Book and Suggested Point Values, below.

Ongoing Assessment: This unit is fun to teach, because it gives you freedom to teach and assess individuals and small groups. Students will stay engaged and absorbed in the work, leaving you free to circulate and check progress. Especially in the early days of the unit, it is crucial not to let students make huge mistakes (for example, bad decisions on the proportion of rooms) with their initial design, on which the entire rest of the unit depends and which they only have one class period to complete.

Detailed Unit Map

Activity	Today's Math	Activity	Handouts and supplies	Homework
1	**Metric measurement.** A. Measuring size of common objects. B. Metric measurements expressed in decimal form (1.2 meters = 1 meter, 20 centimeters).	1. Introduce project 2. Make 1-meter measuring tapes (optional) 3. Review metric measurement and drawing real-world objects to scale.	*Memo One* *Life in Antarctica* *Metric Mania* (optional) *Get the Figures!* Make a 1-Meter Tape Measure Architectural Symbols 1 cm graph paper (5 sheets per student).	Make scale-size cutouts of common household furniture and appliances.
2	Making scale drawings	Create floor plans, calculate initial exterior wall cost.	Graph paper Overhead transparencies taped over graph paper; wipe-off markers Meter tapes or metric rulers.	Evaluate group's design for mathematical correctness
3	Group assessment: scale and proportion	Design review presentations	*Design Review Comment Sheet*	Scale problems from your textbook
4-5	Quiz: Metric measurement and scale drawing Functions with area and perimeter Calculation practice	Revise designs after design review Cutting costs by minimizing exterior perimeter. Recalculate costs Class graph	*Quiz: Scary Harry* *Math that Matters: More living space for your money* *Memo Two* Graph paper, transparencies and markers *Wall Panel Planner*	Area and perimeter problems from your textbook
6	Minimizing surface area	Reduce heat loss through outside surfaces of design: Test surface area of one and two-story	*Memo Three* Calculators Transparencies, markers, graph paper	Surface area problems from your textbook

		versions of designs.		
7	Quiz: Area, perimeter, and surface area Making 3-D models from scale drawings	Make a 3-D model of final station design	*Quiz: Perimeter and Surface Area* *How to make a 3-D Model* Calculators Metric rulers or student meter tapes Poster board (half-sheet per group) Index cards Glue sticks Scotch tape	None
8	Writing functions for real-world problems	Choose insulation level	*Memo Four* *R-value savings worksheet* Calculators	Word problems from your textbook involving writing functions.
9	Review for assessment	Final design write-up	*Memo Five* Previously completed worksheets	Review problems from your textbook if needed.
10	Final assessment		Final Assessment	

Items for your Grade Book and Suggested Point Values

Metric Mania	5
Get the Figures	5
Complete scale furniture cutouts	5
Initial design	20
Fixes on design review comment sheet	10
Quiz: Metric Measurement and Scale	20
Math that Matters	5
Memo Two	10
Memo Three	10
Quiz: Perimeter and Surface Area	20
3-D Model	20
R-value savings worksheet	10
Final report	10
Unit test	30
Group work grade (cooperation)	10
Homework completion	10
Total	**200**

Getting Ready

1. Copy **Design Package** for each student, including:
    - Cover sheet
    - Memo One
    - Life in Antarctica
    - Metric Mania (optional)
    - Get the Figures!
    - Make a 1-Meter Tape Measure
    - Architectural Symbols
    - 1 cm graph paper (5 sheets per student).
2. Gather materials for the unit:
    - Overhead transparencies – at least 4 per group for the unit (Activity 2-6)
    - Large paper for brainstorming
    - Wipe off markers for the transparencies
    - Calculators (Activities 6-10)
    - Scotch tape: one roll per group (Activity 2, 7)

- Glue sticks 2-3 sticks per group (Activity 7)
- White 3x5 index cards (ruled or unruled ok): 1 pack per group (Activity 1, 7)
- Poster board - 1/2 sheet per group (Activity 7)

3. Organize students into groups of 4.

4. **Optional**: Ask your media specialist to create a set of Internet bookmarks for students to use at home to learn more about Antarctica.

We also recommend:

How to Survive in Antarctica **by Lucy Jane Bledsoe (Holiday House, 2006),** which is a quick and lively account of the author's three trips to Antarctica and all the ins and outs of everyday life there.

Activity Cluster 1: Assignment Antarctica

Activity Cluster One Overview

The purposes of today's activities are to;

(1) introduce students to the problem they will be solving (designing a research station for a scientists who will do research in Antarctica and to Students receive *Memo One*, which explains the problem; and,

(2) to review **metric measurement** and **scale drawing**.

In class:

1. They read Memo, read *Life in Antarctica* for background.

2. They spend time meeting the scientists who will work and live in their station. Individually, they imagine and write a schedule for a day in the life of their scientist.

3. As a group, they brainstorm a list of what the scientists need and want in their station and create a list of as many things scientists will need in the station.

4. They get a sense of the real-world size of the site where their station will be built by making a meter tape and using it to measure their classroom and their desk, and review scale by drawing the objects they just measured to scale on a grid map of the site.

For homework, students measure items in their homes and make scale-size cutouts of each item so they can use them to judge the sizes of rooms in their designs. We have found that without these reference items, students tend to make their drawings wildly inaccurate – usually much too big.

Student Handouts

Design Package (see Getting Ready, above).

Other Supplies

Scissors and tape for each student (to cut and assemble the meter tapes)

3x5 index cards (3 per student – for homework)

Introduction (10 minutes)

Give each student a Design Package and go over Memo One. Give students time to read "Life in Antarctica. Ask students to discuss anything else they know about Antarctica.

Some points to make about the unit:

1. In each activity cluster they will solve a different math challenge as they work on their design. The challenges will use some math concepts they already know and some that may be new or used in a new way.

2. In every activity they will use math to make their design more responsive to the scientists needs. That means it's going to change a lot from beginning to end.

3. The design will be a group product, but there will be jobs for every individual and everyone will hand in their own final report and take their own tests and quizzes. Explain how you will assess the unit.

4. Everything in this unit is based on the work real designers and architects do. Students should never be wondering, "When would anyone use this math?"

Learn about your scientist and his/her needs (25-30 minutes)

Purpose: Start to put a human face on the design challenge. Each student gets a scientist to design for (Scientist hand-outs). They start to delineate the scientist's needs.

What to do: They should read the description of their scientists, explore resources on Antarctica on the web, then write a typical day schedule for their scientists. They should be sure to include time for any special activities that their scientists must engage in or enjoy very much.

Make a meter tape (10 minutes)

Purpose: Review **metric measurement** and provide each student with a measuring tool to use throughout the design process.

What to do: Explain that because this is a scientific research station, all measurement is done in metric units (the measurement system scientists use in their work.) Give each student scissors and tape and let them cut out and assemble the meter tape from the handout.

Alternate plan: You can use centimeter rulers or meter sticks for the next activity, and let them assemble the meter tape as part of their homework.

How Big is the Site (15 minutes)

Purpose: Review **scale drawings**, give students a sense of how big the research station site is in the real world, and improve students' sense of how big a meter and a centimeter are in the real world.

What to do: Have students outline the site (15m x 20 meters) drawn to a 1cm:1m scale on graph paper. Then have them measure their desks and the classroom with their meter tapes, and then draw them to scale on the same graph paper.

Optional or Alternate activity: Take the class outside and have them mark off a site 15 x 20 meters.

Assessment: Collect the drawings. Use them to make sure everyone understands the basics of making a scale drawing. Assign additional work from your textbook on

Activity 2 if necessary.

Optional: Metric Mania

Purpose: Review key aspects of metric measurement for students who need it.

What to do: Give everyone the handout and do parts one and two as a whole class activity. Students can do Part 3 as part of their homework.

Possible Solutions to Metric Mania Handout:

1. This chart gives students a chance to relate the metric system to objects with which they are familiar — either to objects in the world or to the standard units of measurement. Most students will have less intuition when if comes to how big the different units of metric measurement are.

Metric unit	About the same size as …
Millimeter	the tip of a dull pencil
Centimeter	half an inch
Meter	a little longer than a yard
Kilometer	a little more than half a mile

2.

1 kilometer =1000 meter = 100,000 centimeters =10,000,000 millimeters

1 meter =100 centimeters=1000 millimeters =.001 kilometers

1 centimeter =10 millimeters =.01 meters = .00001 kilometers

3. Using the chart you can see that there are 100,000 centimeters in 1 kilometer. Multiply this by 2 to calculate how many centimeters there are in 2 kilometers. The answer is 200,000 centimeters.

Homework: Get the Figures (10 minutes)

Purpose: To provide practice in measuring in meters/centimeters and expressing metric measurements in decimal form. To give students scale representations of common household objects that they can use to size the rooms in their research station.

What to do: Go over the handout "Get the Figures."

Explain that when students are making scale drawings of their design, it will be helpful to have scale representations of beds, stoves, and other common household items, in order to judge how big each room needs to be. They're going to make little cutouts of each item to stick on the paper as they work.

They will be using a scale of **1cm: 1m.** (You can pose that as a question: "What would the scale be if I wanted to make the drawing twice as big?").

Students will measure the items on the chart at home and make scale drawings on index cards or graph paper, using the sheet “Architectural Symbols.” Index cards are good because the cardboard is sturdier.

If you suspect students may not have the items at home, or if students don’t do the homework, have them do the activity with school fixtures.

If they want to measure other objects they may invent their own symbols.

Do a quick example to demonstrate how to make the cutouts.

Some of the cutouts will be very small, so it’s not necessary to be highly accurate.

Approximate responses (student answers will vary)

Item	Length (m)	Width or Depth (m)
Bedroom		
Bed	2.5	1 (single)
Dresser	1	0.6
Bathroom		
Toilet	0.75	0.5
Shower	0.75	0.75
Bath Tub	1.5	.75
Sink	0.85	0.5
Kitchen and Dining Area		
Stove	0.7	0.75
Refrigerator	0.75	0.80
Kitchen Sink	0.55	0.64
Table	1.9	1
Chair	0.5	0.6
Living Room		
Couch	2	1
Chair	1.5	1
Doors, Windows, and Stairs		
	Width	Height
Window	1.0	0.25
Doorway	2.05	1.07

Individual Design ideas

If you have time left in the period, give students some time to sketch design ideas individually on a plain piece of paper.

Advanced Study Ideas for Activity Cluster One

1. Statistics: Advanced students can poll groups for ranges of sizes for a given item – for example, what was the range of lengths and widths for a bathroom sink. They can offer the class an average size to use and perform other useful statistical analyses (identifying outlier values, for example).

MEMO ONE

To: ANTARCHITECTS

From: Booker *Vega*, Principal Designer

Re: Welcome new hires!

Greetings and welcome to **ANTARCHITECTS**, a design and architecture firm specializing in designs for cold climates. We aim to meet the needs of our clients. We hope you'll feel right "AAT" home in your new job.

We also hope you're ready to get right to work because we've got a hot (or rather, cold) new client: **The Frozen Scientific Group.**

Frozen Scientific needs to build a new research station in Antarctica, where their scientists study climate change. They had to abandon their current research station because of flooding near the site. They have decided to relocate to a nearby site further from the coast.

You will be designing the main building of the station for the four scientists who live there year round. They expect to use the station for 20 years. Here are the requirements.

1. The site is a field of flat dry rock, 15 meters x 20 meters.

2. The building includes:
   - Sleeping quarters for four scientists
   - 1 bathroom
   - Research lab (need at least 36 square meters of floor space for equipment)
   - Entryway for storing, putting on, and taking off outdoor clothing.

3. Livability: You must make the design meet the needs of the scientists who will be there for over one year.

Frozen Scientific will judge the designs according to two criteria:

1. Includes all required rooms and fits on site (30 points).

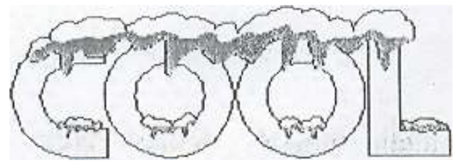
2. Layout of is clever and attractive, uses space efficiently, and is responsive to the lifestyle and needs of the researchers in a harsh climate. (30 points).

LIFE IN ANTARCTICA

Cold, Dry Antarctica

Antarctica is cold. Even at the coast, where the temperatures are warmest, the temperature averages around -40°C in the winter, and warms up to freezing level in the summer (0°C) Although people think of Antarctica as a cold, snowy place, it is in fact a desert. It gets less rain or snow than the Sahara Desert. The air is very dry.

Wintering Over…



Each winter, the research bases in Antarctica close for seven to nine months. During this time, no one can come to or leave the base, because travel is too dangerous. Most researchers work only in the summer, but at each base a small crew stays at the base to keep things going over the winter. The experience of staying through the winter is called "wintering over." It can be a difficult experience.

...at the South Pole

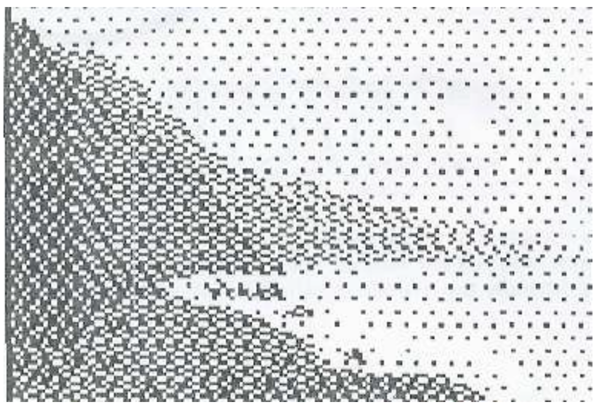
Wintering over is hardest at the Admundsen-Scott Station at the South Pole. For one thing, temperatures are coldest there, sinking below -73°C. Also, the sun sets in the winter and doesn't reappear until spring. Even when there is sunlight, the people in the station rarely see it. First, there are only two small windows at the Station, and second, the weather is often too harsh for people to go outside. The long period without natural light makes people feel more isolated. The lack of natural light also has a big effect on people's moods. One year a research team put much brighter lights in the station, and people's moods improved.

People naturally depend on daylight and darkness to help them know when to sleep. When the sun sets for the winter, people in the station tend to drift into a 25-hour schedule, which means they wake up an hour later each day and go to bed an hour later each day. After several days they find themselves awake and ready to work in the middle of the night. This only works for people who have work they can do any time of the day. Others must stick with a regular schedule, and sleep at the same time every day. The two groups often disturb each other's sleep, which causes arguments.

Since space at the station is limited, people have trouble finding a place to get away from the group for a while. Arguments can happen over small things, but can seem very important when you're stuck with the same small group for months on end and no one can leave the base. People sometimes make elaborate changes in their routine to avoid having to eat at the same time as the person they're angry with.

Loneliness can be a problem. An airplane drops mail at the station only once during the wintering-over period at the South Pole People can sometimes communicate by ham radio or Internet, but often choose to stay isolated rather than hear about things at home that they can't do anything about.

So what do people do when they're not working? They watch videos, take short walks outside, listen to music, talk, and sleep. Sometimes the group will decide to work on a special project together — one group built a Jacuzzi.



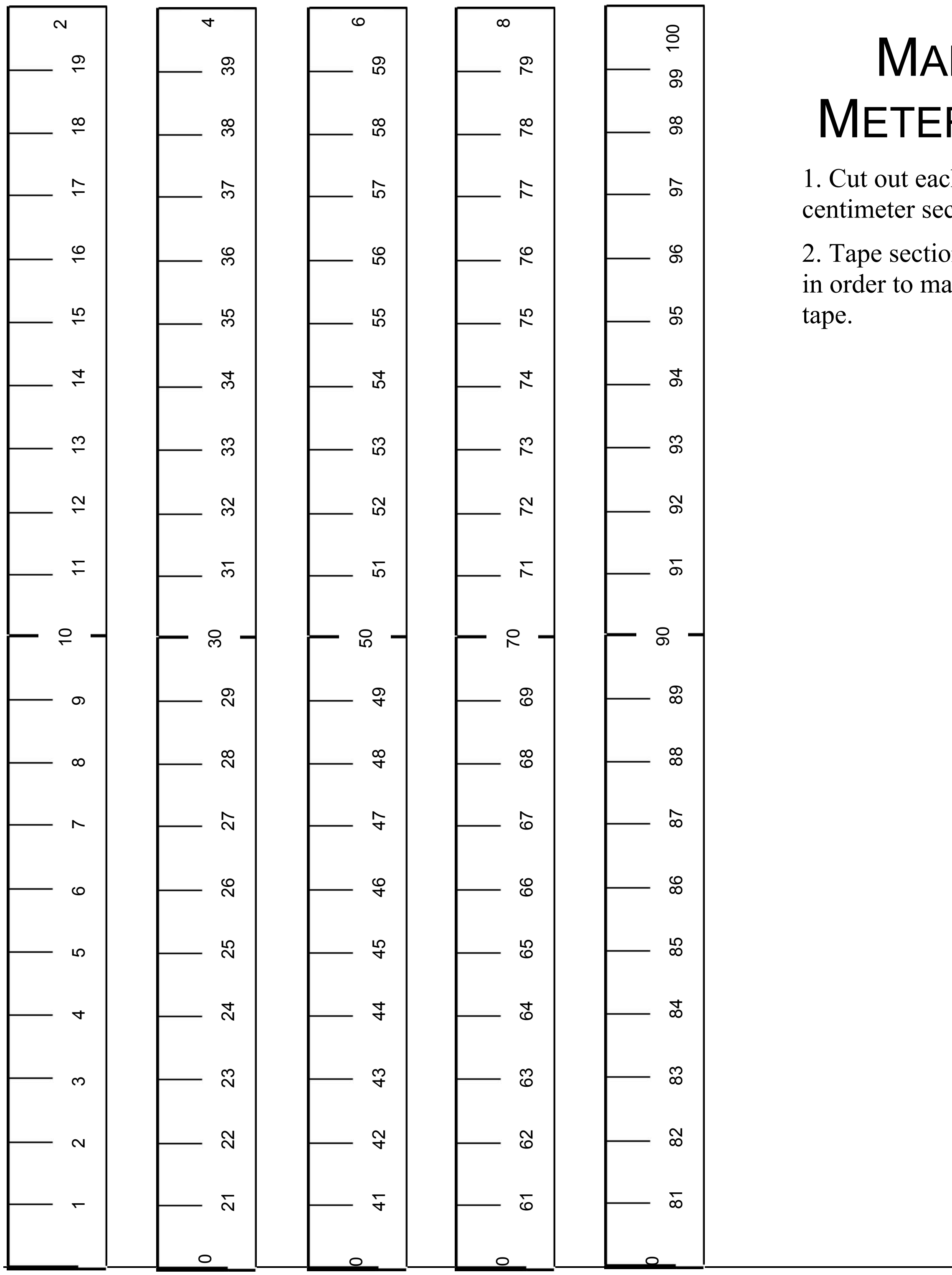
…at the Coast

Life at the coastal stations isn't quite as hard as life at the South Pole. Palmer station has many windows, but the thin walls in the station are a problem. Your neighbor[1] can hear every move you make and every word you say. This lack of privacy can make life difficult.

Looking out from the Carry base, you see only ice. Even though the station is on the coast, you can't see the ocean. That's because the ocean is completely frozen in pack ice for as far as you can see. For a couple of weeks in the summer (January), the ice breaks apart and the ocean makes a brief appearance.

The weather at these stations is milder than at the pole. Most days have at least a few hours of sunlight, and people can go outside more. But the isolation is still hard on the wintering-over crew, who face many of the same problems as the South Pole crew.

*(Information from Patrick E Cornel "Life in Antarctica", Marc Levesque: "An Experiential Perspective on Conducting Social and Behavioral Research", and Sidney M. Blair, "The Antarctic Experience" in From Antarctica to Outer Space. Edited by Harrison, Clearwater, and McKay. 1991 Springer Verlag, New York.)



MAKE A METER TAPE

1. Cut out each 20-centimeter section.
2. Tape sections end to end in order to make one long tape.

Metric Mania

1. Fill in the chart:

Metric Unit	About the Same Size As
millimeter	
centimeter	
meter	
kilometer	

Complete the following conversion chart for the metric system

1 kilometer = 1000 meters	1 kilometer = ______centimeters	1 kilometer = ____ millimeters
1 meter = 100 centimeters	1 meter = ______millimeters	1 meter = ____kilometers
1 centimeter = 10 millimeters	1 centimeter = ____meters	1 centimeter = ______kilometers

How many centimeters are there in 2 kilometers?____________

Explain how you got your answer.

GET THE FIGURES

Furniture will help you get the sizes of rooms right in your design.

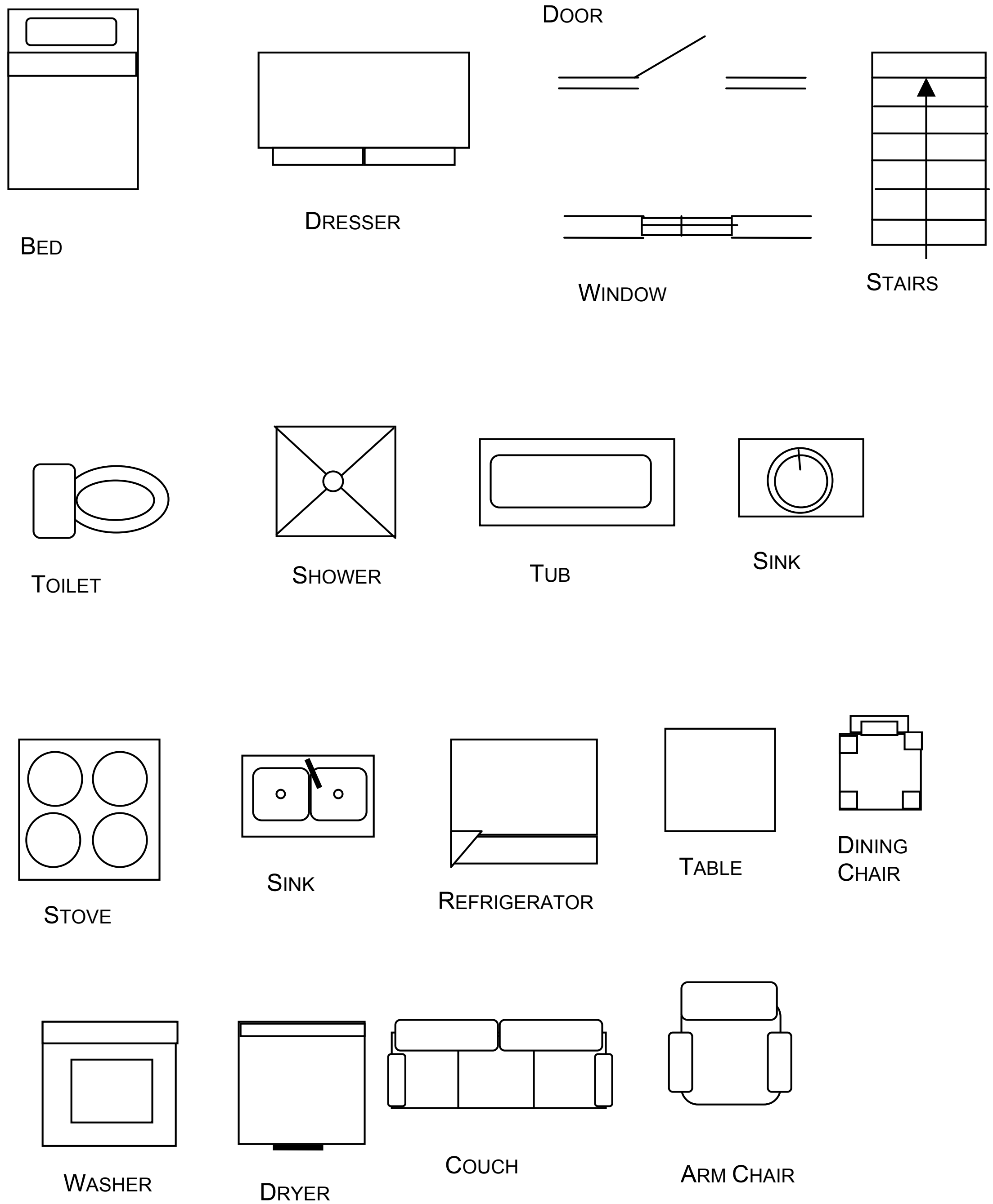
1. Measure the top or bottom surfaces of these items in your home and fill in the following chart. **Remember you'll be drawing them as seen from above.**

Use **decimals** to express fractions of a meter – for example 1 meter, 7 cm = 1.07 meters. 75 cm = 0.75 meters.

<table>
<tr><th>Item</th><th>Length (m)</th><th colspan="2">Width or Depth (m)</th></tr>
<tr><td colspan="4">Bedroom</td></tr>
<tr><td>Bed</td><td></td><td colspan="2"></td></tr>
<tr><td>Dresser</td><td></td><td colspan="2"></td></tr>
<tr><td colspan="4">Bathroom</td></tr>
<tr><td>Toilet</td><td></td><td colspan="2"></td></tr>
<tr><td>Shower</td><td></td><td colspan="2"></td></tr>
<tr><td>Bath Tub</td><td></td><td colspan="2"></td></tr>
<tr><td>Sink</td><td></td><td colspan="2"></td></tr>
<tr><td colspan="4">Kitchen and Dining Area</td></tr>
<tr><td>Stove</td><td></td><td colspan="2"></td></tr>
<tr><td>Refrigerator</td><td></td><td colspan="2"></td></tr>
<tr><td>Kitchen Sink</td><td></td><td colspan="2"></td></tr>
<tr><td>Table</td><td></td><td colspan="2"></td></tr>
<tr><td>Chair</td><td></td><td colspan="2"></td></tr>
<tr><td colspan="4">Living Room</td></tr>
<tr><td>Couch</td><td></td><td colspan="2"></td></tr>
<tr><td>Chair</td><td></td><td colspan="2"></td></tr>
<tr><td colspan="4">Doors, Windows, and Stairs</td></tr>
<tr><td></td><td>Width</td><td>Height</td><td>Depth</td></tr>
<tr><td>Step (each)</td><td></td><td></td><td></td></tr>
<tr><td>Window</td><td></td><td></td><td>xxxx</td></tr>
<tr><td>Doorway</td><td></td><td></td><td>xxxx</td></tr>
</table>

2. Find the blueprint symbol on the Architectural Symbols page.
   - Make scale-sized cutouts of each item you measured.
   - Re-draw that symbol on an index card to represent the size of the object you just measured, using a scale of **1cm:1m**. **Cut out the symbols you drew**.

ARCHITECTURAL SYMBOLS



Activity Cluster 2: Making a Preliminary Design

Overview of Activity 2

The purposes of Activity Cluster 2 are to:

(1) Brainstorm and ideate around the needs of the scientists in the harsh environment of Antarctica. They conduct a bit more research on Antarctica, have a group brainstorming session, and ideation activity to decide requirements for their designs. They use what they are learning about Antarctica, *Memo One*, the "day in a life" they each made to create a requirements list for their station.

(2) develop students' real-world sense of metric measurement and their scale drawing skills. The process of designing the research station offers repeated practice in figuring out how big something is in the real world, measured in meters, and then drawing it to scale. By the end of the period, students each produce at least 2 scale drawings of research station designs. They use the furniture icons they made for homework to judge the size of each room.

Students work collaboratively drawing and erasing on an overhead transparency taped over a sheet of graph paper. When they settle on a design, each student makes an individual copy on his or her own sheet of graph paper.

Student Handouts

Two or more sheets of 1-cm graph paper for each student. You may purchase this or photocopy the page included in this unit.

Other Supplies

- Large sheets of paper for brainstorm and ideation (2 per group)
- Overhead transparency sheets (2 per group)
- Graph paper (2 sheets per group)
- Tape for each group
- A glue stick (optional) for each group
- Wipe-off (non-permanent) markers for each student (for the brainstorm, ideation and transparencies)
- Students' meter tapes from previous day or metric rulers

Go over homework (10 minutes)

Let group members exchange data and fill in their data tables so everyone has a full table. Do a quick check in a whole-class session, asking each group to call out a few measurements and checking for outrageous variations.

Continued Research & Brainstorming Session (25 minutes)

Purpose: Students take what they are learning about Antarctica and the needs of their scientists and brainstorm work, social and private needs of the scientists.

What to do

1. Allow students to conduct more research on Antarctica and lives of scientists.

2. BRAINSTORM. (5 minutes). Show students clips of good and bad brainstorming and discuss rules for good brainstorms.

3. Each group should have a marker and paper. They should brainstorm on the topic of "Needs of the scientists." They should have all the materials about Antarctica and their scientists, including the day in a life schedules. When they brainstorm they should accept all answers and write as many ideas of needs they can generate.

4. Call time. Ask each group to look at their brainstorm and have each person check or put a star next to 4 "needs" they think are important.

5. Have them save these sheets for tomorrow.

Assessment: Walk around as students are working and encourage them to add more ideas. Make sure all choose 5 as ones they think are important.

Sketch preliminary designs (35 minutes)

Purpose: Students apply their understanding of metric measurement and scale drawing to the problem of designing a research station.

What to do

1. Today, students will try individual designs. Tomorrow, they will complete a group design. Today is for generating many possibilities.

- Students will **make their design surface** by taping an overhead transparency over a sheet of graph paper.
- Each student should have a **marker and a paper towel or cloth** for erasing.
- **Explain that** by drawing on the transparency, and students can easily revise their design without having to redraw the whole thing on new paper.
- Tell students to use the underlying grid to **draw everything to a scale of 1 cm: 1 m.**
- Suggest that students make a habit of **marking each wall they draw** with its real-world length. That way they don't have to keep counting grid lines every time they need to make a change.
- Students should **use the furniture they cut out for homework** to judge the size of each room. They can **draw furniture on their designs or use tape loops or glue sticks** to hold the furniture in place while they work, while making it easily movable.
- **Each student should make 2 station designs**.

2. **For 25 minutes**, allow students to use the transparencies to sketch out an

arrangement of the rooms specified in *Memo One*. They may have multiple levels (first and second floors, for example) or not. They can use their brainstorm of needs for inspiration

3. **For the last 5 minutes**, have each group member paste up their designs and look at them. They may want to explain each. This is sharing, and more brainstorming.

Assessment: Walk around as students are working and ask them to prove that their rooms are a reasonable size.

Homework or in class journal

Each student should write a quick evaluation of one of his or her designs:

1. Does the design include all the required rooms?

2. Is each room a reasonable size? That is, big enough to use for its intended purpose and hold necessary furnishings, but not wastefully large?

3. Does the design meet the needs of his/her scientist, Memo 1 and the brainstorm?

Advanced Study Ideas for Activity 2

Students can explore irregular or non-square shapes for designs. For example, what if the lab were not square – what are some attractive, non-square ways to make a lab – for example, a circular, window-rich shape protruding from the rest of the station? How could this shape still have the required 36 square meters of floor space? Would all the space be usable, given the curved walls? How big of a circle would you need to get 36 square meters of square space?

Activity Cluster 3: Design Review

Overview of Activity 3

The whole-class design review is a way for you to **assess students' understanding of scale, metric measurement** as applied to the research-station design task. Students may realize only on seeing other students' designs that they have made rooms much too big or small, or have left out important aspects like hallways or doors. The whole-class review tends to raise the quality of every group's design.

Student handouts

Design Review Comment Sheet

Other Supplies

Overhead Projector

Student designs

A piece of graph paper photocopied onto a transparency.

Group meetings (10 minutes)

Purpose: Make each student aware of features and flaws in the group's design.

What to Do: Give students time to share their homework in their groups and decide what they'll say during the design review. Explain that you won't be looking for a perfect design, but you will want evidence that they understand the problems and plan to fix them.

Assessment: Students should turn in their homework at the end of the period. Mark for completeness.

Design Review (35 minutes)

Purpose:

1. Assess students' ability to use scale drawing and metric measurement to create realistic and reasonable solutions to the Research Station design problem.

2. Review measurement and scale-drawing skills for students who are having trouble.

What to do:

1. **Appoint a "scribe"** for each group. It is the scribe's job to take notes during his or her group's presentation in the first column of the **Design Review Comment Sheet.**

2. **Presentations:** Each group removes the overhead transparency of their design from the graph paper it's taped to, and puts it on the overhead on the transparent graph paper. Each group presents to the class in turn, using the following suggested structure.

(1-2 minutes): Presenters "walk" the class through the floor plan, explaining the reasoning behind the layout: For example, a group might say, “We decided to put the bedrooms on this side so the noise from the recreation area wouldn’t disturb anyone’s sleep.”

(1 minute): Presenters share known flaws discovered overnight and changes or other additions the group plans to make. For example, “We realized our bedrooms are too small for a bed and a dresser.”

(1-2 minutes): Discussion. Students may make positive comments (“I like the shape of the entry way,”), or specific suggestions (“I think your bedrooms need to be at least 3 meters.”). At the end of the discussion period, note any important problems the class has not noticed, *particularly mathematical issues with scale and proportion.*

At the end of each presentation, ask the scribe to list the issues the group needs to resolve and make sure they agree with your own list.

Assessment

Use the following criteria to evaluate each group’s presentation and give each student a group grade.

10 points: Design has all rooms specified in *Memo One*, or students have noted any missing features in their presentation.

10 points: Most rooms are reasonable real-life sizes, and students have noted any problems during their presentation.

Homework:

If students need practice with scale and metric measurement, assign problems from your regular textbook.

If any group needs to re-do their design from scratch, each student in that group should draw a layout for homework to speed things up the next day.

If students did a great job with their initial drawings, tell them that since they are doing so well they’ll have no homework tonight.

Tell students there will be a quiz on measurement and scale tomorrow.

Design Review Comment Sheet

Group Names:____

Requirement	**Suggestions/Problems**	**Fix**
Fits on site and contains all required rooms.		
Attractive, sensible layout.		
Rooms and furniture are reasonable sizes.		

Activities 4 and 5: Quiz, Revision, Perimeter and Floor Area

Overview of Activities 4-5

After a quiz **assessing individual understanding of scale and metric measurement,** students examine the relationship between **area** and **perimeter**. They discover that they can reduce the cost to build their station without losing any floor area, by making it more square. They write their first **function** – to calculate the total cost of exterior walls for their design, and distinguish variables and constants.

Student Handouts

Quiz: Scary Harry's Bus

Math that Matters: More living space for your money

Memo Two

Exterior Wall Panel Guide

Other Supplies

Metric rulers or student meter tapes

Centimeter graph paper, transparency-covered graph paper & markers

Calculators

Quiz: Scary Harry's Tour Bus (10 minutes)

Purpose: Assess scale drawing and real-life metric measurement.

What to do: Give each student a *Scary Harry* handout.

1. Give 1 point for each reasonably-sized and correctly scaled item (room and furnishing). Student answers will vary, but here are some ranges for reference.

    Bed: about 2 meters long by 1-2 meters wide.

    Table: 1.5 -2.5 meters long by 1-2.5 meters wide

    Bathroom Sink: .5 - .75 meters long, .5 deep.

2. Responses should match what the student drew.

3. Responses will vary, but should refer to the sizes of what goes in a bathroom (it's big enough for a sink, toilet, and shower), or the size of a person (my bathroom is about as long as my dad and as wide as me).

4. Response should match what student drew in #1, but with a scale of 3cm: 1m.

Area and Perimeter Discussion

Background: In today's lesson, students will be ordering the exterior wall panels for their buildings. Modern construction in Antarctica tends to use prefabricated components. Keep in mind that whoever puts the building together is going to be working in sub-zero temperatures and high wind, with little shelter. So the buildings have to go up quickly and easily.

The prices and insulation information for wall panels were obtained in 2007 from a real company that makes prefabricated wall panels that have actually been used in Antarctica. These panels have highly efficient insulation built right in, and are strong enough to replace the usual framing. Buildings go up much faster and the insulation is better.

Purpose: Students learn that math can help them make a better design. They revise their designs to make them more accurate (fixing problems uncovered in the design review). They also learn they can cut costs by optimizing the design to reduce its perimeter (making it more square). Finally, they learn to create functions for total perimeter and total wall cost.

What to do: Pass out *Memo Two*. In this stage of the design process, students are asked to submit their order for the prefabricated wall panels from which their station will be built.

1. Provide background: Go over the memo and explain that in Antarctica, modern builders rely on prefabricated parts as much as possible, because it's so hard to build in the extreme wind and cold. Builders build as much as they can in a warehouse at home, and then ship the wall segments to Antarctica for final assembly. Conveniently, these panels come in one-meter widths, so the number of panels they need is the same as the perimeter of the design (or the total perimeter of all stories if students have a multi-story design).

The basic wall panels cost $147.00, for a panel that is one meter wide and three meters high.

2. Discuss:

- Ask students what they will have to know in order to calculate the total cost of wall panels for their design. Possible answers include "the size of the building," "the price of each prefab panel," "the perimeter of the building," and "the height of the building."
- Tell students they can write an equation to calculate the total cost from all these other quantities. They will do that by the end of the activity.
- Ask: Which of these will stay the same, no matter which design? These will be **constants** in your equation. Which quantities will be different for different designs? These will be the **variables** in your equation.
- Ask: If you wanted to save money on wall panels, what could you do? Students will probably say "Make the building smaller." The next example shows that you could save money while maintaining the same floor area.
- Work through an example: Say we have a building 20 meters wide, 8 meters deep. How many wall panels will you need? (20*2 + 8*2 = 56 meter perimeter, so 56 wall panels). How much floor area does the building have? (20*8=160 sq. meters). Now change the shape of the building while keeping the floor area the same: 16 meters wide, 10 meters deep. Floor area is still 160 sq. meters, but now the perimeter is only 104 square meters. At $147.00 per panel, that would be a savings of 8 panels or $1,176.
- If any students have **two story designs**, remind them to add the perimeters and floor areas of both floors.

Math that Matters: More Space for your Money

Purpose: Encourage students to use mathematical analysis to improve their designs; review area and perimeter concepts.

What to do

1. Let students do the handout individually.
2. Discuss in a whole-class format. Focus on the last question – how can this help them improve their designs? Ask students to share ideas with the class.

Assessment:

1. Possible rectangles include 1x36, 3x12, 4x9, 6x6.

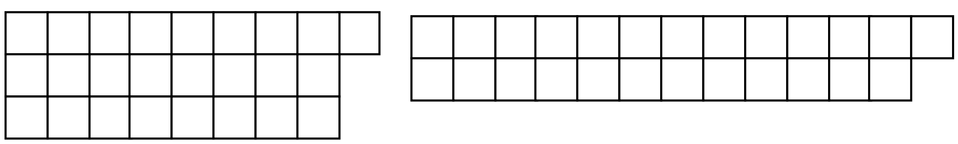
2.

Length	Width	Perimeter
1	36	38
3	12	30
4	9	26
6	6	24

3. 6x6. 36 panels x $147.00 per panel = $5,292.00

4. 5x5 square would be cheapest. The only other rectangle is 1x25. Many irregular shapes, including:

P=24
P=29



5. This question relates real-world ideas to mathematical ones: "wall panels" = perimeter, and "floor space" = area. Students can minimize the perimeter by making the building more square, because a square is the smallest perimeter that encloses a given area.

Revision and Wall Panel Reduction

Purpose: Students fix scale and proportion issues uncovered in the design review, and apply the lesson on reducing perimeter to their designs.

What to do: Put the boxed instructions on the board and go over them. Then let students work on their designs.

Today's Tasks

1. Revise designs to fix problems uncovered in the design review.
2. Follow the instructions on the *Exterior Wall Panel Guide* to calculate cost for exterior wall panels.
3. Make at least one improvement to your design using what you've learned about area and perimeter. Calculate the savings in wall cost. Then fill in the bottom of *Memo Two* and turn it in.

Assessment: Each group should turn in their *Design Review Comment Sheet* with the "fixes" column filled in, describing how (or whether) they addressed each problem in the first column, and their completed *Exterior Wall Panel Guides* and *Memo 2*.

Memo 2

1. Response = The perimeter of their original design * $147.00

2. They may have cut costs by cutting out wasted space or by making the building more square.

3. Response = The perimeter of their revised design * $147.00

Exterior Wall Panel Guide

1. The cost for exterior panels = the price per panel (here a constant, $147) * the number of panels. Responses should be of the form EP = 147 (n) where n = number of panels.

2. Responses will vary.

3. Cost = 147 * the total perimeter in response #2.

Homework

Assign word problems from your textbook relating to area and perimeter.

Advanced Study Ideas for Activity 4

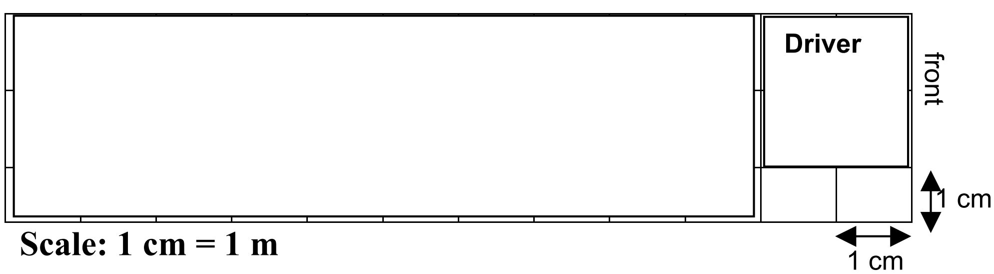
Students can explore area and perimeter implications of irregular and curved structures. For example, how do area and perimeter relate in an elliptical or cylindrical lab? Which has the smaller perimeter, a square lab with 36 square meters or a circular one? For irregular rectangular shapes (for example, an "L" shape), is perimeter minimized if each part is a square, or if the L itself fits in a square?

QUIZ: METRIC MEASUREMENT AND SCALE
SCARY HARRY'S TOUR BUS

Scary Harry, the **mega rock star**, needs a new **tour bus** to carry him around the country on his Mock Rock Tour. You are responsible for designing the interior of this bus. Harry needs a place to sleep, a place to hang out with the band and practice, and a bathroom. The band sleeps in another bus.

1. (6 pts.) On the bus diagram below, make a rough sketch showing how you would divide the space between the three rooms needed (bedroom, practice room, bathroom). Then draw

- √ A **bed** in the bedroom.
- √ A **sink** in the bathroom.
- √ A **table** (large enough to seat 6 people comfortably) in the practice room.



Scale: 1 cm = 1 m

2. (6 pts.) Based on your sketch, what is the real-life size of each room?

Bedroom: ________meters front to back, ______meters side to side.

Bathroom: ________meters front to back, ______meters side to side.

Practice Room: ________meters front to back, ______meters side to side.

3. (2 pts) Explain how you know that the bathroom you made is a reasonable size.

4. (6 pts.) Scary Harry is getting older, and he has trouble seeing tiny floor plans. He wants a bigger drawing of the practice room. On the back of this sheet, use your ruler and a scale of 3 cm = 1 meter, to redraw the **practice room** and the **table** you made above.

MATH THAT MATTERS: MORE ROOM FOR YOUR MONEY

Can the shape of your station affect its cost? This investigation will help you get more station for your money!

1. Pretend for a moment that the lab is a separate building. Draw two labs that each has the required 36 square meters but different wall perimeters.

2. How many rectangular or square building shapes could you make that each has an area of 36 square meters? Fill in the chart below for each shape you can make.

Length	Width	Perimeter

3. Each meter of wall costs $147.00. What would be the least expensive 36-square-meter lab shape to build? ____________ How much would it cost? _____________

4. Based on the chart you just made, can you predict what shape with 25 square meters would be least expensive to build? Make a table to support your prediction, using both rectangular and irregular shapes.

5. Based on 1-4, how can you save money on wall panels without losing floor space?

MEMO TWO

To: ANTARCHITECTS

From: Booker *Vega*, Principal Designer

Re: Wall Panel Order

Antarchitects, Inc. builds all our buildings from prefabricated exterior wall panels. These panels are made from the latest Earth-friendly materials and have insulation built right in. Using these pre-made panels saves us many steps during construction – and that saves money!

Frozen Scientific is on a tight budget, so please look for ways to reduce the number of wall panels your design will require, without sacrificing the comfort of the scientists who will live there.

Use the Wall Panel Guide to calculate your current wall panel budget. Then try to improve your design to cut costs, and return this memo with your savings.

Group Members:___________________________________

Initial Exterior Wall Panel Budget: $_____________

What you did to cut costs:____

____

____

Revised Exterior Wall Panel Budget: $______________

EXTERIOR WALL PANEL GUIDE

Wall Panel Specifications

Height: 3 m

Width: 1 m

Price: $147

1. Create a function that gives you the total cost for exterior panels (EPC) given the number of panels needed (n).

EPC = ________________________________.

2. Fill in the perimeter values for your design below:

Perimeter

First Floor Perimeter	________	meters
Second Floor Perimeter	________	meters
Total perimeter	________	meters

Number of Panels Needed ____________________

3. Use your function to find the total cost for the exterior wall panels your design needs.

EPC for our design: $__________________

Activity 6: Surface Area

Overview of Activity 6

In today's lesson, students will try to minimize heat loss in their structures by **reducing the structure's total surface area.**

Student Handouts

Memo Three

Other Supplies

Calculators

Transparency-covered graph paper, markers, individual graph paper

Surface Area Discussion

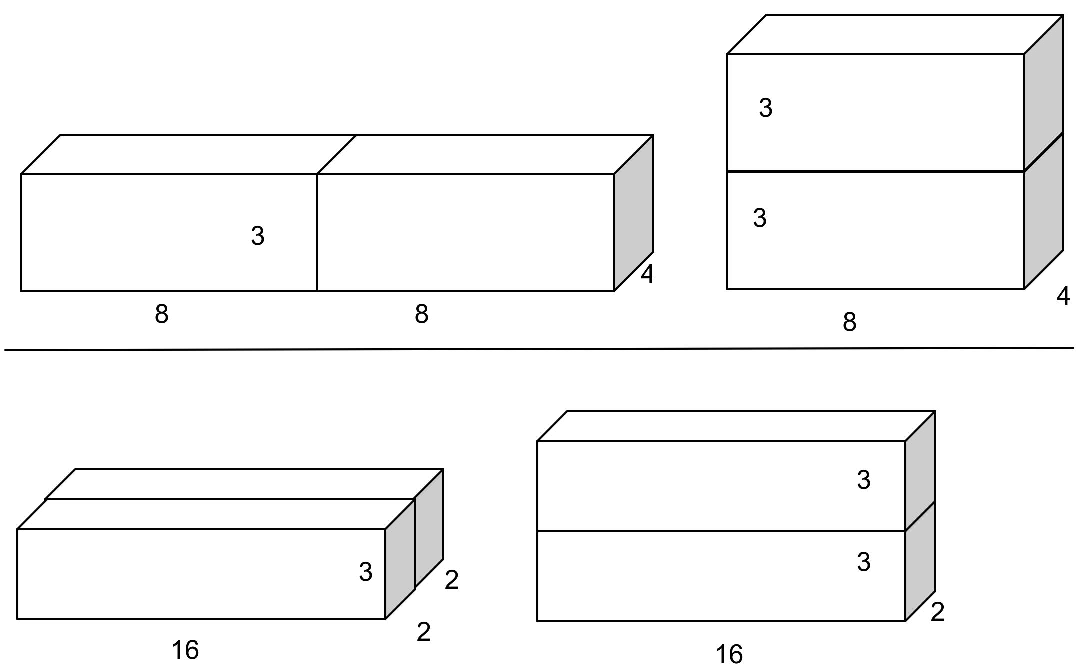
Purpose: Explore the behavior of a surface area function by changing the building shape.

Background: Students are challenged to reduce the surface area of their station, because reducing the surface area reduces heat loss. Students may have an intuition that a two-story station will have a smaller surface area than a one-story station with the same floor area, because a cube is the smallest rectangular prism, to enclose a given volume.

For most student designs, the two-story version *will* have a smaller surface area. But it is possible for the one-story design to win, if the base is long and skinny.

Below are two ways to enclose a volume of 192 cubic units. **In the top example**, the surface area of the one-floor design is 248, and the two-story design is **less**, at 208.

In the bottom example, the one story surface area is 248, and the two story surface area is **greater**, at 280.



It comes down to the area of the shared surface, which is either the area of the surface between the top and bottom floor of the two-story design or the area of the shared wall in the one-story design. And that means the two-story design will win unless half the width of the one story design is less than the height. That's what's special in the bottom example: 2 < 3.

What to do:

Go over *Memo Three*.

Ask students to make a hypothesis about which would have a smaller surface area – a one story design or two-story design.

Calculate the surface area of the two examples above as a whole class exercise, to show that the outcome isn't certain and to review how to calculate surface area.

Let students make new versions of their design and fill in the questions in *Memo Three*.

When everyone has finished, ask each group to report back. Probably all will say that, even adding a stairway, the two-story version has a smaller surface area. Ask them to figure out what was so special about the long skinny prism in the second example above, and see if they can make a general statement about the behavior of surface area between one and two story versions.

Homework

Surface area problems from your textbook

Advanced Study Ideas for Activity 6

Advanced students can continue applying the today's lesson to irregular and curved shapes. They can also explore the following question and create conjectures with supporting arguments. They can share the results with the class as "design tips."

For a given floor area, will making a square base reduce both wall cost (perimeter) and surface area?

What is a general procedure for "cubifying" a design, keeping the rooms the same size? How do you know you've got the best possible solution?

MEMO THREE

To: ANTARCHITECTS

From: Booker *Vega*, Principal Designer

Re: Surface Area and Heat Loss

As you no doubt remember, Antarctica is a very cold place! Heating the research station will be a major operating expense for Frozen Scientific.

Heat escapes through the walls, roof, windows, doors – even the floor! Any heat that escapes needs to be re-generated (by burning more fuel), and that costs money.

The amount of heat lost is a function of the total surface area of the building. We can save Frozen Scientific money by making the total surface area as small as possible.

Please create two versions of your design – a single story and two-story version. If your design is currently one story, make a two-story version. That means you should add a stairway and put about half of the station "upstairs," keeping the same general layout otherwise. **But don't throw away your original – you may need it!**

Adding a stairway: A stairway is one meter wide, 4.5 meters long, and 3 meters tall.

If your station is currently two or more stories, make a one-story version. That means you should place the stories side-by-side or front-to-back on one level and add appropriate doorways, and a hall if necessary. **But don't throw away your original – you may need it!**

1. Calculate the surface area of each version – the one story and the two-story.

Surface area: One story ___________ Two-story _________________

2. Decide which version will be your final, and justify your selection. You do not need to choose the one with the smallest surface area, but if you choose the one with larger area you'll have to explain why it's worth the extra money. If your group can't agree, write a justification for each design.

Activity 7: Quiz and Make a 3-D Model

Overview of Activity 7

On Activity 7 students take a short quiz so you can assess their understanding of area, perimeter, and surface area concepts from activities 4-6. Then students make a 3-D model of the station they've designed. The purpose of the activity is to help them students to a more sophisticated, 3-D understanding of scale and surface area.

Student Handouts

Quiz: Perimeter and Surface Area

How to make a 3-D Model

Other Supplies

Calculators

Metric rulers or student meter tapes

Poster board (half-sheet per group)

Index cards

Glue sticks

Scotch tape

Quiz

1. (A) P=20, A=16; (B) P=50, A= 150; (C) P=48, A=80
2. 1x16: P=34m, 8x2: P=20m; 4x4: P=16m
3. Student could say that the 4x4 has the smallest perimeter and so would cost the least to build. Or, they could say something like this and still get credit: "Even though the 4x4 is cheapest to build, I would choose the 8x2 if lab tables are long and narrow."
4. 390 square meters.
5. One story: 584 sq meters. Two story: 448 sq. meters

Make a 3-D Model

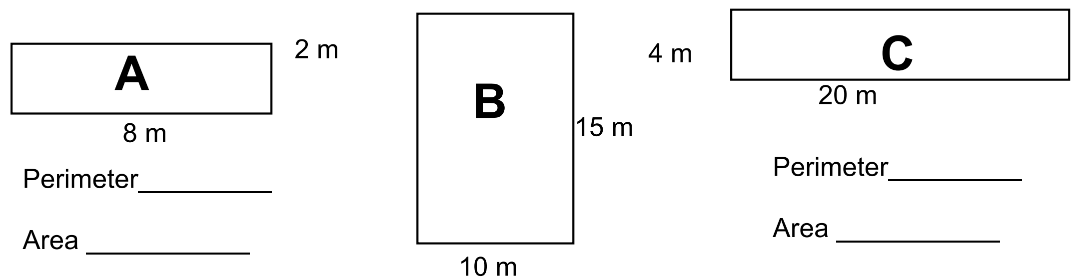
Purpose: Help students visualize and understand the mathematical relationships they've discovered in the previous activities; provide more practice working with scale.

What to do:

1. Go over the handout, "How to Make a 3-D model."
2. Hand out graph paper. Have students divide up their design into fourths (for a 4-student group, thirds for a 3-student group, etc.). Have each student re-draw a section of the design with a scale of 5mm: 1m. Have them tape together their sections to make a complete floor plan drawn large.
3. When students have completed their floor plan, give them poster board, index cards, glue sticks, scissors, and tape. The tape isn't strictly required, but it comes in handy when the glue stick glue won't hold.
4. If students have multiple floors, they should do each floor individually and stack them.

QUIZ: PERIMETER, AREA, AND SURFACE AREA.

1. Fill in the perimeter and area of each of the following rectangles. (3 pts.)



A: Perimeter_________ Area ___________

B: Perimeter_________ Area ___________

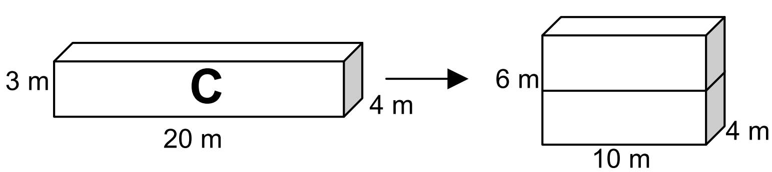
C: Perimeter_________ Area ___________

2. Using only whole numbers, list the other rectangles you can make that have the same area as rectangle A but different perimeters. (6 pts)

3. Suppose you want to save money. If you design a storage shed with the same area as Rectangle A, explain which of the rectangles you would choose from the list you made and **why**. (5 pts)

4. If Rectangle B is the floor of a two-story research lab with a total height of 6 meters, what is the surface area of the lab? (2 pts)

5. Rectangle C is the floor of a one-story research lab. Your group decides to cut and stack it to make a two-story lab with the same floor area. (4 pts)



What is the surface area of each lab?

One story _____________ Two story________________

HOW TO MAKE A 3-D MODEL

1. Draw your floor plan with a scale of 5mm: 1m. You may need to tape together several sheets of graph paper to do this.

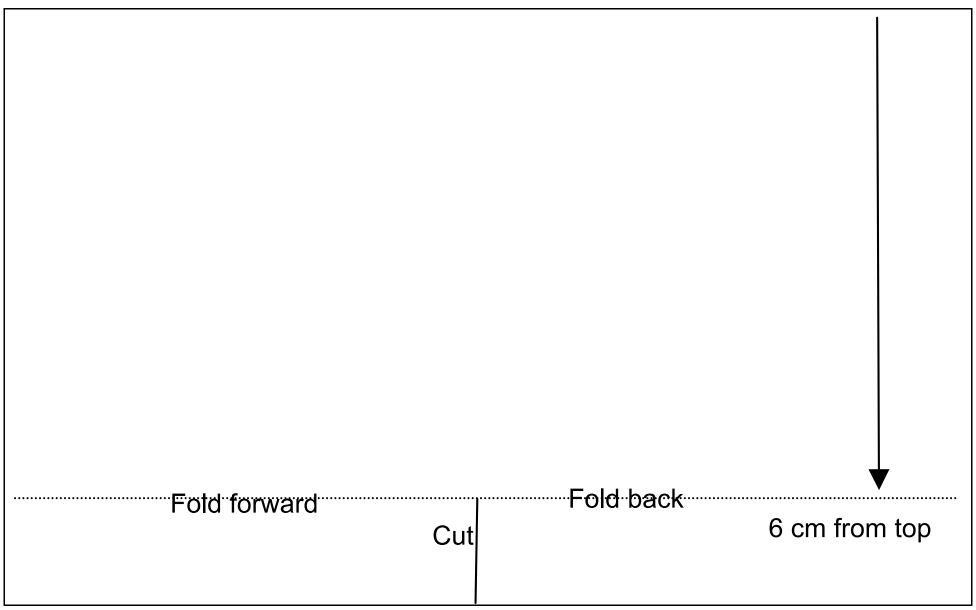
2. Use your glue stick to glue your floor plan onto a piece of poster board.

3. Assign jobs to each group member. Jobs include:

- Card Prep: Fold index cards to the correct height and cut the flaps.
- Exterior walls: Glue index card "exterior walls" onto the design
- Interior walls: Glue index card "interior walls" onto the design.
- Furniture: Make furniture cutouts using your "Get the Figures" sheet and the new scale of 5mm: 1m, and glue them in place.

4. How to measure, fold, and glue index cards

- Walls are 3 meters high, so you need to make 6 cm walls.



- Cut along the solid vertical line that says, "Cut."
- Fold along the dotted line: inward on the left half and outward on the right. That will make flaps for the card to stand on.
- If there is a door or a window on this section of wall, draw it to scale on the card. You can and cut it out if you like (leaving the hinge side of a door uncut will give you a door that opens and shuts).
- Trace the wall line on your floor plan with a glue stick. Then press the flaps onto the glue to make a wall.
- Overlap cards slightly so there is no gap between them.

Activity 8: Functions for evaluating insulation needs

Overview of Activity 8

In Activity 8, students **create functions to solve a complex, multi-step real world problem**. Students are guided through a complex decision: choosing insulation levels for their station. To do so, they must figure out how many months it will take for better (more expensive and effective) insulation to pay for itself in reduced heating costs.

Student Handouts

Memo Four

R-value Savings Worksheet

Calculators for each student

Choosing Insulation

Background: R-value is a measure of how well a wall resists heat loss. When you buy insulation for a home or commercial structure, you can choose among several R-values of insulation. The higher the R-value, the thicker or more dense the insulation and the better it works.

It turns out that better insulation is fairly cheap and pays for itself fairly quickly. In real construction in Antarctica, they use the best insulation they can fit into the walls, sometimes insulating up to R-50. The company that makes the panels we based this unit on offers panels up to R-38.

We calculated the cost per month of heat loss through each panel using generally accepted equations for heat loss through walls:

Heat loss = Area of the surface / R-value of the surface.

We used the metric equivalent of R-value, RSI (Resistance, Standard International).

To calculate the cost, we multiplied the heat loss in kilowatt hours by the cost per kilowatt hour, and then multiplied that by 730 hours per month.

Purpose: Students add and subtract square meters, express real-world questions in algebraic form, and work through a multi-step problem to answer a real-world question.

What to do: Go over *Memo Four*. Ask students to float ideas about how they could answer the questions at the bottom, and what they think the answer might be.

Then have the students work through the *R-Value Savings* worksheet, either in a whole-class discussion or in small groups.

At the end, students may be surprised to find that no matter how big or small a design is, the break-even point is always the same: **20 months for R-32, and 28.2 months for R-38**.

R-value Savings Worksheet

1. wc=n*c

2. wa = n*s – wi – d. Students will have to figure out the window and door areas for their

design.

3. fc = mc*wa*n

7. b=ec/ms

9. R-38, because it doesn't take long to pay for itself compared to the 20-year expected life of the station.

10. Yes, it will be the same for any design. That's because both the cost and savings are per square meter, so the function works for any number of square meters.

Advanced Study for Activity 8

Students can explore how heat lost cost relates to building cost. Is the heat lost per dollar spent linear? That is, what is the ratio between heat loss cost per month and building cost per square meter for each insulation value? Is it the same for any insulation?

MEMO FOUR

To: ANTARCHITECTS

From: Booker *Vega*, Principal Designer

Re: Insulation and Heat Loss

The Frozen Scientific Group does not want their researchers to actually freeze! So they are concerned about making their station as energy efficient as possible.

The amount of heat lost through the walls of a structure is a function of how much wall there is and how well the wall resists heat loss – which means how much insulation is in the walls.

The wall panels we use are available with a choice of three levels of insulation. The level of insulation is measure in units called R-value, where R stands for Resistance to heat loss.

The table below shows the three R value (insulation) choices, the price per square meter of wall, and the cost of the heat lost through that square meter of wall, in dollars per month.

R-value	Purchase price for each square meter of wall	Cost per month for heat lost through each square meter of wall
R-38	$60	$.76
R-32	$54	$.90
R-25	$49	$1.15

Should we use **R-25** panels or better? If we use **R-32 panels**, how long will it take until they pay for themselves in energy savings?

What about if we use **R-38** panels instead of **R-25?** How long will it take until they pay for themselves in energy savings?

Please use the attached worksheet to calculate your savings.

R-VALUE SAVINGS WORKSHEET

1. Write a function for calculating how much you'd spend buying wall panels (wc) for your design, using these variables:

n= Number of panels purchased (from Memo Two)
c = Cost per panel

wc = ____

Use your function to calculate total wall panel price for all three levels of insulation **for your design.**

R-25_________ R-32 ____________ R-38_____________

What is the extra cost for the walls **in your design?**

Extra Cost 1: R-32 instead of R-25: _________________

Extra Cost 2: R-38 instead of R-25: _________________

2. Write a function for calculating the **total wall area in your design** (wa), in square meters, not counting windows or doors, using these variables.

n	Number of wall panels
s	Size of each panel, square meters
wi	Total Window area (square meters)
d	Total Door area

wa =____

Now, use your function to calculate the wall area for **your design.**

wa = __________

3. Write a function for calculating the fuel cost (fc) of lost heat through walls **for a whole design** with these variables:

mc	Cost per month of lost heat through walls per square meter
wa	Square meters of wall space
m	Number of months

fc = ____

4. Use your function to calculate the cost per month for your design of heat lost through the walls for each R-value's monthly cost per meter.

R-25__________ R-32_____________ R-38 _______________

5. How much would your design save each month on heating by using R-32 instead of R-25?

$___________ per month

6. How much would your design save each month on heating by using R-38 instead of R-25?

$ ________ per month

7. Write a function for calculating the **number of months it will take to break even (b)**. That means you will have saved as much on heating as you spent buying the better insulation. Use these variables:

ec	Extra amount spent for better insulation
ms	Monthly savings using better insulation

b=__________________________.

8. Use your function and the extra cost values from question 1 to fill in the blanks below.

Months to break even (R-32):________ **Months to break even (R-38)_____**

9. What insulation level do you recommend for the walls in your design? Why?

10. Would this result be the same for any design? Explain.

Activities 9 and 10: Final Report and Unit Tests

Overview of Activities 9 and 10

On Activity 9, each student prepares a final report. They explain the features and justify them mathematically to prove that the design complies with the requirements originally set out in *Memo One*.

Activity 10 is a unit test.

Student Handouts

Memo Five

Unit Test

Other Materials

Students will need access to their final designs and all the worksheets they completed.

Final Report

Purpose: To help students review the math they used and summarize their work on the unit.

What to do: Give each student a copy of *Memo Five*. If you like, students can work together in their groups or alone, but each student should turn in their own copy of *Memo Five*.

Homework on Activity 9

Assign review problems from your textbook for any problematic areas covered in the unit test.

Unit Test

1. Students can draw three rectangles: 8x8, 4x16, or 2x32. (1x64 won't fit on the paper). They could also draw any irregular shape that has a 64 square meter area.

2. Whichever shape has the smallest perimeter would be cheapest to build.

3. Yes If they did not draw an 8x8 square – length = 8 and width = 8.

No if they did draw a square. They can be sure because a square is always the smallest perimeter to enclose a given area.

4. 2cm:2m or 1cm:1m or any equivalent ratio.

5. p=110*n

6. n is a variable, 110 is a constant.

7. The table should be about .75 meters to 1 meter square. The chairs should be about a half-meter square.

8. Surface area for possible rectangles:

8x8: 224 square meters

4x16: 248 square meters

2x32:332 square meters

9. a: 64 panels b: 128 square meters c:320 square meters

10. y=.50s

MEMO FIVE

To: ANTARCHITECTS

From: Booker *Vega*, Principal Designer

Re: Insulation and Heat Loss

Congratulations! You've finished working on your design. We are preparing to submit all the designs to Frozen Scientific. Please answer the following questions so we can let them know the great features your design has, according to the three criteria given in Memo 1.

1. Includes all required rooms and fits on site (30 points).

(a) Check off each room if it is included in your design.

[ ] 4 bedrooms

[ ] 1 bathroom

[ ] Research lab (need 9-10 square meters of space floor space for equipment)

[ ] Kitchen, and dining area

(b) Give the outside dimensions of your building's "footprint" to show that it fits on the site (15x20 meters maximum).

2. Layout of rooms is clever and attractive, uses space efficiently, and makes sense for lifestyle of a researcher in a harsh climate. (**30 points**).

(a) Explain the layout – why the rooms are arranged the way they are.

(b) Explain why you made the rooms the size they are. Be specific ("not too big and not too small" is not going to tell Frozen Scientific much).

(c) Explain why you chose a one-floor or two-floor layout. Be specific and use numbers where you can.

(d) Explain how you chose the level of insulation and why you think it's a good decision.

(e) Describe any other special features of your design

THE ANTARCTICA PROJECT
UNIT ASSESSMENT

Frozen Scientific is very excited – they just got approval to add a second building to their station – a small library! They plan to build a one room structure that will allow them to store lots of books.

1. The building will have **64 square meters of floor** area. **Using a scale of 1 cm:2m,** draw two possible shapes for the 64 square-meter library.

Scale 1cm:2m

2. Label the shapes you drew in Question 1 A and B.

Which would be cheaper to build, A or B?_______

Why?

3. Is there a shape with a floor area of 64 square meters that would be even cheaper to build?

If yes, write the length and width here __________.

If no, explain how you can be sure:

____

____

______

4. To make your drawing appear twice as large as the ones above, what scale would you use?

__________ : _________ .

5. The scientists just heard about a great sale on wall panels - just $110 per panel. They're going to buy some extra panels but they haven't decided how many yet.

Write a function to calculate the total price (p) for any number (n) of wall panels at $110 per panel.

p = ________________________________ .

6. In your function in #4, which term is a VARIABLE? ___________________.

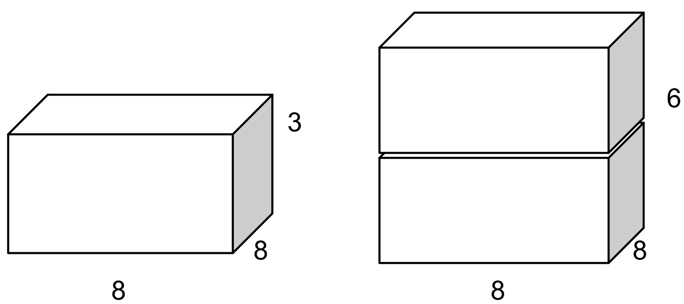
Which term is a CONSTANT? _____________________.

7. The library will have a **square table with four chairs**. Estimate reasonable sizes for these items and draw them on one of your plans, to scale (1cm:2m).

8. Assuming the walls are 3 meters tall, calculate the surface area for each building you drew.

Surface area A: ___________________ Surface Area B:_________________________

9. Suppose the scientists decided to add a second story to the library.



(a) How many 1m x 3m wall panels do the scientists will need for the two-story library?______________

(b) What is the floor area of the two-story library? _________________

(c) What is the surface area of the two-story library? _________________

10. The scientists calculate that they can save $.50 per square meter per month by upgrading to better insulation. Write a function to calculate how much they will save per year (y) for a building with "s" square meters.