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Junior Architects: Designing Your Dream Clubhouse Using Measurement and Geometry

This department features children's hands-on and minds-on explorations in mathematics and presents teachers with open-ended investigations to enhance mathematics instruction. These tasks invoke problem solving and reasoning, require communication skills, and connect various mathematical concepts and principles. The ideas presented here have been tested in classroom settings.

A mathematical investigation—

- has multi-dimensional content;
- is open-ended, with several acceptable solutions;
- is an exploration requiring a full period or longer to complete;
- is centered on a theme or event; and
- is often embedded in a focus or driving question.

In addition, a mathematical investigation involves processes that include—

- researching outside sources;
- collecting data;
- collaborating with peers; and
- using multiple strategies to reach conclusions.

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Edited by **Patricia S. Moyer,** *pmoyer@gmu.edu, George Mason University, Fairfax, VA 22030. This section is designed for teachers who wish to give students new insights into familiar topics in grades K–6. This material can be reproduced by classroom teachers for use with their own students without requesting permission from the National Council of Teachers of Mathematics. Readers are encouraged to send manuscripts appropriate for this section to "Investigations," NCTM, 1906 Association Dr., Reston, VA 20191-1502.*

Although this department presents a scripted sequence and set of directions for an investigation, the NCTM Standards (NCTM 2000) encourage teachers and students to explore multiple approaches and representations when engaging in mathematical activities.

This month's investigation involves numerous mathematics Standards appropriate for students in grades 3–5. The major concepts include using basic linear measurement, understanding and creating scale representations, and exploring perimeter and area. In this two-week project, third-grade students worked in Junior Architect teams to design a "Dream Clubhouse." As students designed and described their clubhouses, they identified, compared, and analyzed attributes of two- and three-dimensional shapes and developed geometry vocabulary.

At the core of this project was the problem-solving process, which provided a context in which students learned concepts and skills. The Dream Clubhouse project was set in a real-world situation. Students developed procedural fluency and strategic competence by budgeting money, measuring geometric forms, and using geometry principles. The following sections outline specific activities during the ten-day project. These daily lessons delineate the mathematical processes that children used to design their clubhouses and the mathematics learning that resulted from their participation in the activities.

Planning the Project

In planning the project, the teacher placed importance on developing a learning experience that contextualized measurement and geometry concepts in a way that would be personally meaningful to the children. Providing multiple levels of intellectual

challenge for students with different abilities also was essential. A constructivist philosophy and several essential elements of problem-based learning formed the basis of the teacher's planning.

One of the most important elements of the project was the creation of authentic activities and contexts. The teacher presented the mathematical tasks in the Dream Clubhouse project in a real-life context. This strategy contextualized learning for the students because they used mathematics as a tool to accomplish the tasks. The teacher based her design of these tasks on her belief that students learn mathematics through *knowledge construction*. Her problem-solving activities focused on students developing their own solutions, instead of the teacher "telling" students what to do. She wanted students to learn to identify what they did not know and, as a group, to work to extend their own understanding. This required the process of *knowledge collaboration*, in which students worked collaboratively in small groups to solve problems that were important to their work in the design of the clubhouses. Students worked cooperatively and then presented multiple solutions to classmates with opportunities to engage in "what if" thinking.

The teacher also placed an emphasis on problem solving and exploration. The project promoted higher-order thinking skills such as planning, formulating problems, mathematical calculation, and decision making. The teacher monitored student growth through writing and reflection. She told students to write entries in an architect-design log to reflect on their problem-solving experiences and record their progress. This type of metacognitive engagement encouraged students to assess their

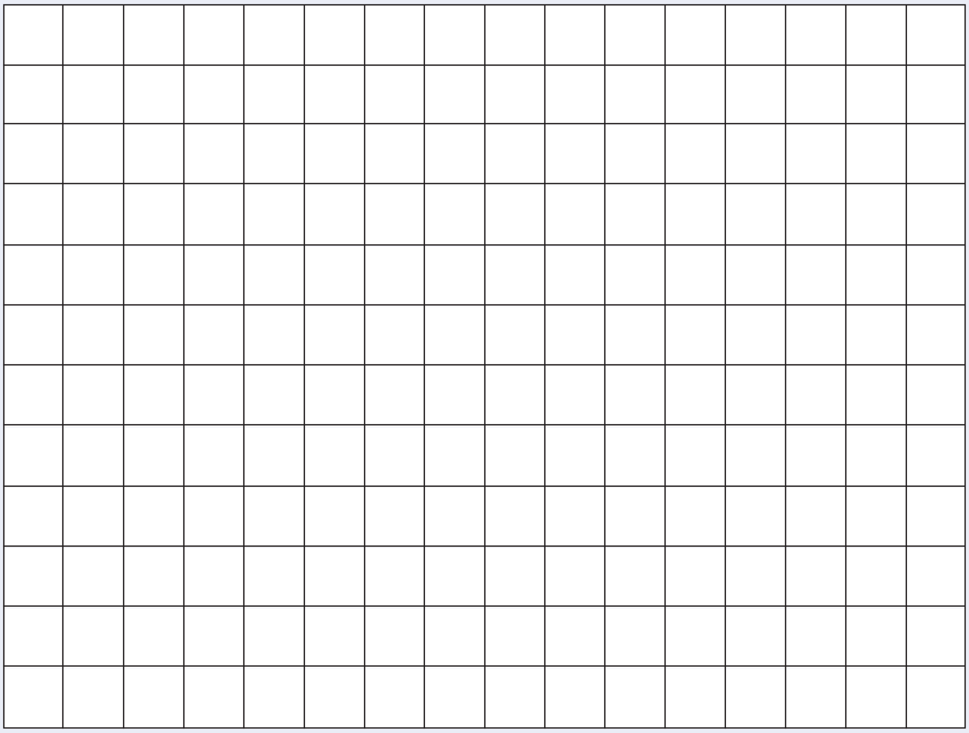
Figure 1

Classroom measurement activity

Make scale drawings of the following:

teacher's desk	chalkboard	area rug
student's desk	sink area	computer station
door	bookshelves	
windows	TV stand	

(Each square represents 1 square foot)



own need to better understand certain concepts in order to solve problems. The teacher also wanted to use an authentic assessment of the students' clubhouse projects. She reviewed students' blueprint designs, three-dimensional models, journals, and clubhouse budgets to evaluate the success of their final projects.

Introducing the Project (Day 1)

The teacher read the books *How a House Is Built* (Gibbons 1986) and *Building a House* (Barton 1981) to stimulate student interest in the project. As she read the stories, she pointed out the variety of buildings in the text and discussed their purposes. She also posed questions to find out what the students knew about building structures. After reading the stories, the teacher reviewed the pages of the books to give students an opportunity to identify different geometric shapes used in the buildings. She asked students to look for symmetry and congruence in the buildings. The book *Math in the Real World of Architecture* (Cook 1996) also is a good teacher resource for exploring these concepts. The teacher concluded the discussion by highlighting the importance of geometric shapes in the structure of a building, and she explained that students would be studying how mathematics relates to building and design.

The teacher also invited an architect to talk to the students about his job and how mathematics relates to his work. He showed the students measuring tools that he uses to draw blueprints, and he presented pictures and models of different types of architecture. The level of excitement during his visit made it easy for the teacher to motivate students to take on the authentic task of creating their own clubhouse projects.

During the last part of the lesson, students gathered in small teams of two or three to decide on a theme for their clubhouses and to make a list of all the items that they believed were essential to include in the clubhouse. The themes that the students selected included sports, animal lovers, art, and dance. Students' task for the next two weeks was to learn the mathematics skills required for designing an architectural structure and then to build scale models of their clubhouses. Teachers can complete all the Day 1 activities in an extended mathematics lesson or over the course of two or more lessons.

Geometric Solid Figures (Day 2)

On the second day, the teacher brought in everyday items such as milk cartons, cereal boxes, and oatmeal containers as examples of geometric solid figures. The focus of this lesson was to show students how a three-dimensional model appears when it is drawn as a two-dimensional representation. The students used the milk cartons to represent townhouses and the cereal boxes to represent apartment buildings, and they used other items to identify faces, edges, and vertices of solid figures. They opened the milk cartons and cereal boxes and cut along the sides of the containers to transform them into nets, the two-dimensional representations used to create three-dimensional objects. This spatial-visualization task was important for students because they would design two-dimensional representations of the clubhouses and furniture prior to making the three-dimensional objects.

Perimeter and Area (Day 3)

The next day, the teacher wanted students to begin to develop a sense of size so that they could determine dimensions for their clubhouses that were realistic and proportional to human size. To develop these spatial concepts, the teacher placed tape on the floor of the classroom in a variety of rectangular shapes with different dimensions to represent different room sizes. The teacher posed the question "How would you compare the different room sizes?" Students' responses included measuring the length and the width to find the total distance around the tape. The teacher took advantage of this idea to introduce the concept of perimeter. As the class discussion continued, one student discovered that he could count the number of tiles on the classroom floor. In fact, the classroom tiles happened to be twelve inches by twelve inches, or one square foot. With this new discovery, students were able to use the floor tiles to determine the area of each room by counting the number of square feet.

After the class discussion, students estimated and then measured the size of the classroom. They used graph paper to make scale drawings of furniture in the classroom. Students used the classroom measurement activity sheet (see **fig. 1**) to complete their drawings.

Figure 2

Architectural criteria for the blueprint

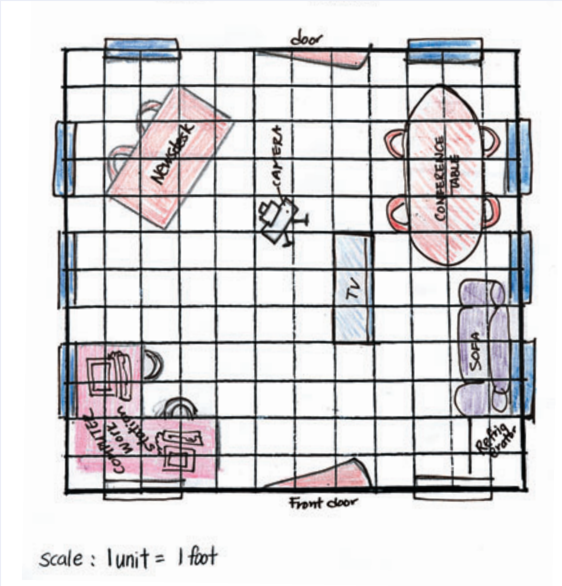
Design a scale drawing of your clubhouse on inch graph paper. A scale is a proportion between two sets of measurements. When architects draw plans for a house, they cannot draw the plans the same size as the real house they wish to build. Therefore, they must scale the drawing down to a smaller size. For example, each inch equals a foot and each square inch represents one square foot. Remember to use the "Architectural Criteria" to guide you in your design.

Architectural Criteria

1. Total perimeter cannot be more than 48 feet.
2. Total square footage cannot be more than 150 square feet.
3. The house can be only one level that is no higher than 10 feet.
4. The house must have a door and not more than eight windows at least 1 foot apart.
5. Placement of furniture and fixtures must be indicated.
6. All walls, doors, and windows must be drawn with 90-degree angles and must be perpendicular to the floor.

Figure 3

Blueprint for the newsroom clubhouse



For homework, students measured and recorded the size of their bedroom at home and listed items in their architect-design logs that they wanted to include in their clubhouses. The teacher asked them to come to class the next day with a sense of their clubhouse dimensions and prepared to justify their selection.

Two-Dimensional Blueprints (Days 4 and 5)

For this part of the project, the teacher brought in several blueprints from different builders for students to explore. This task required students to create their own representations of the clubhouses by designing a scale drawing. The teacher used the blueprints to help children identify architectural symbols for structures such as doors, windows, and walls. The teacher worked with the students to create architectural criteria that they would need to follow in constructing their clubhouses (see **fig. 2**). Next, students used the theme for their clubhouses to develop the scale blueprint on inch graph paper. They included all exterior features on their floor plan, such as doors, windows, and walls. Each inch square represented one square foot, and they used the conventional symbols for doors and windows (see **fig. 3**). Later, they added furniture items, drawn to scale, to the floor plan.

Students used several sheets of graph paper until their drawings were correct. One student drew a doorway only one inch long and then realized that it would be only one foot wide. He went to the classroom doorway, measured the entrance, and found that he should make the doorway at least three inches long, which would be one yard (three feet) wide. Because the idea of creating a scale drawing was new to the students, the teacher took time to discuss and share examples of scale drawings of other familiar items such as a map of their classroom, school, and neighborhood.

Using the blueprints, students designed the front, back, and sides of their clubhouses. They used inch graph paper and the nets they had drawn on the second day to create scale drawings of the walls. They determined what size their walls needed to be to match their blueprints, figured out the size and location of their windows, and calculated a measure for the height of the door. Finally, students turned in their blueprints with measurements, net drawings, and all the specifications to the teacher.

The Construction Phase: 3-D Models (Days 6 and 7)

The building inspector—the teacher—inspected the design of the clubhouses. She evaluated the blueprints to determine whether students had adhered to the architectural criteria. She checked to be sure that students had blueprints with straight lines, ninety-degree angles on all doors and windows, and proper spacing of windows and doors. After the building inspector approved the designs, she gave students poster board or cardboard pieces to begin construction of three-dimensional scale models. Students measured the walls using the calculations and drawings on their blueprints, and then cut them out. They cut four rectangular walls from the poster board pieces and two rectangles and two triangles for the roof. Then they taped these pieces together and began the calculations and measurements. They used the scale drawings on the graph paper to help place the doors and windows and used protractors to make sure that the openings were perpendicular to the floor.

This task of transferring the measurements from the blueprint to poster board and building the model was very challenging for the junior architects. Students needed practice using the ruler to measure in inches and in fractions of an inch. One advantage of the project was that students learned how to use a ruler properly in a meaningful context, rather than as an isolated skill for measuring segments or static pictures. The students were measuring with a tool, revising their drawings, and designing with a purpose in mind.

Unlike textbook problems, this problem-based project allowed for many explorations with student-generated problems. That is, the problems that students encountered were not prefabricated but genuinely created by students based on the task of designing the clubhouses. Students asked questions such as "How can I fit a door and three windows in the front of my house? What should the dimensions be? How many feet should be between the windows and doors?" These self-generated questions encouraged students to focus on attributes of geometric figures, the language of describing shapes, and relationships among those shapes. Activities that involve mathematical communication encourage the development of descriptive language and communication about relationships, important skills for developing the Descriptive and Informal Deduction levels of geometric thinking (van Hiele 1999). Examples of these discussions occurred when students were determining the livable square footage of the clubhouses. These discoveries and explorations motivated students and allowed for student ownership in their mathematical learning. For the next several days, students worked through several problem-solving scenarios that further investigated these mathematics concepts.

Decorating the Clubhouse: Real-Life Problem Solving (Days 8 and 9)

While many students were finishing construction of the model clubhouse, others were ready to decorate their clubhouses. The teacher presented sev-

Figure 4

Budget sheet for house décor materials

Name ____

Materials Order Form for Clubhouse Model

Item	Price	Quantity Ordered	Total Amount
12" × 12" poster board (drywall)	$1.00		
12" × 12" cardboard (drywall)	$1.00		
Cellophane (5" × 5")	$0.25		
Construction paper (1)	$0.20		
Fabric (12" × 12")	$0.25		
Foil (5" × 5")	$0.25		
Gift wrap (12" × 12")	$0.45		
Tissue paper (12" × 12")	$0.20		
Wallpaper (1 piece)	$0.50		
Button (1)	$0.05		
Modeling clay (1 stick)	$1.00		
Paint and sponges	$0.50		
Pipe cleaner (1)	$0.15		
Plastic bottle cap (1)	$0.05		
Popsicle sticks (5)	$1.00		
Straw (1)	$0.05		
Toothpicks (10)	$0.15		
Yarn (12")	$0.10		

Figure 5

Clubhouse showcase

eral open-ended problem-solving tasks involving area, perimeter, and money concepts for students to make decisions about decorating their own clubhouses. In one of the tasks, students compared prices from three different paint stores and determined which store gave them the best bargain on paint. Next, they determined how many cans of paint they needed to cover the interior area of the walls of the clubhouses. They recorded this information on the "Junior Architect's Mathematics Tasks" reproducible worksheet. (Tasks 1 and 2 were modified from Robinson 2001.)

After students worked on the problems, they were ready to decorate their clubhouses. The budget was set at $10 for buying items to decorate the clubhouses. The teacher brought in items such as buttons, colorful straws, cellophane paper, wallpaper samples, toothpicks, fabric swatches, and aluminum foil for students to purchase. Students were creative in using the materials within the constraints of their budgets (see **fig. 4**). Students used bright buttons for doorknobs and decorations, cellophane paper to create stained-glass windows, fabric swatches to make curtains for the windows, and aluminum foil to make solar panels (which made the clubhouses more energy-efficient) and satellite devices (to pick up the sports channels).

Clubhouse Showcase (Day 10)

On the last day of the project, students presented their clubhouses to the class (see **fig. 5**). To prepare for the showcase, they read through their daily reflective logs and wrote a summary report on what they learned during the project. The teacher required them to use as many measurement and geometry concepts and terms as possible to successfully complete the report. Then the students displayed their model clubhouses along with their design summaries. Students toured the showroom and marveled at their classmates' accomplishments.

The teacher's focus during the evaluation phase was as much on the learning process as it was on the final clubhouse products. During the two-week project, she used non-traditional assessment methods such as anecdotal notes, records from group discussions, and students' written responses in their architect-design logs. Students had opportunities to discuss individual and group solutions for each problem. Students' articulation in class discussions and reflection on their thinking processes demonstrated their understanding of many complex ideas. The teacher created a rubric to assess various aspects of the design of the clubhouse project (see **fig. 6**). The assessment included students' mastery of budgeting money, measuring accurately, constructing a three-dimensional model, solving problems, and writing in their design logs. Sharing the criteria for judging the clubhouses with students helped them assess their own progress throughout the project.

Reflections on the Project

In addition to measuring using customary units, determining the perimeter and area of objects, using problem-solving strategies effectively, and working with budgets and cost analyses, students developed numerous mathematical ideas based on their explorations and self-reflection. The clubhouse project engaged students in authentic and complex problem-solving activities with many opportunities for knowledge construction. As students learned to articulate their own ideas, they also learned to appreciate the multiple perspectives and diverse solutions of others in the class during these discussions. Role-playing as junior architects also was highly motivating for students. The most important outcome of the project was that students were immersed in an authentic experience that reflected the way in which mathematical knowledge is used in real life, and they learned important mathematics concepts through their own curiosity and problem solving.

References

Barton, Byron. *Building a House*. New York: Harper Collins, 1981.

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Gibbons, Gail. *How a House Is Built.* New York: Holiday House, 1986.

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Robinson, Jan. “Let’s Go Home.” *Student Math Notes* (March 2001): 1–6.

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Figure 6

Rubric for assessment of clubhouse project

Performance Tasks	Points (Maximum Points for each category = 4; 4: Superior/3: Good/2: Satisfactory/1: Needs revision) Teacher Comments:			
	4	3	2	1
Calculation on budgeting worksheet	Budget shows no errors in calculation	Budget shows few errors in calculation	Budget shows some errors in calculation	Budget shows major errors in calculation
Accuracy of measurement on blueprint drawing	No errors in measurement and details on blueprint	Few errors in measurement and details on blueprint	Some errors in measurement and details on blueprint	Many errors in measurement and details on blueprint
3-dimensional model	No errors in measurement on 3-D model	Few errors in measurement on 3-D model	Some errors in measurement on 3-D model	Many errors in measurement on 3-D model
Problem-solving tasks	Solved problems with accuracy and showed exceptional, sophisticated strategies	Solved most problems with accuracy and showed good strategies	Solved some problems with accuracy and showed limited strategies	Major misconceptions and poor use of strategies
Design log	Clear, complex, and organized communication of creative ideas	Communication of ideas may include minor gaps or inconsistencies	Communication of ideas may include significant gaps or inconsistencies	Unclear, incomplete, and unorganized communication of ideas

Total Points (20 possible points):
20–16: Excellent
15–11: Good
10–6: Satisfactory
5–0: Needs Revision

Junior Architects' Mathematics Tasks

Use the blueprint of your clubhouse to solve these problems.

Task 1: Painting the clubhouse
You are going to buy paint for your clubhouse. Compare the prices at these three paint stores and find the best bargain.

1. Complete the table below so you can compare prices for 1 through 10 gallons of paint.

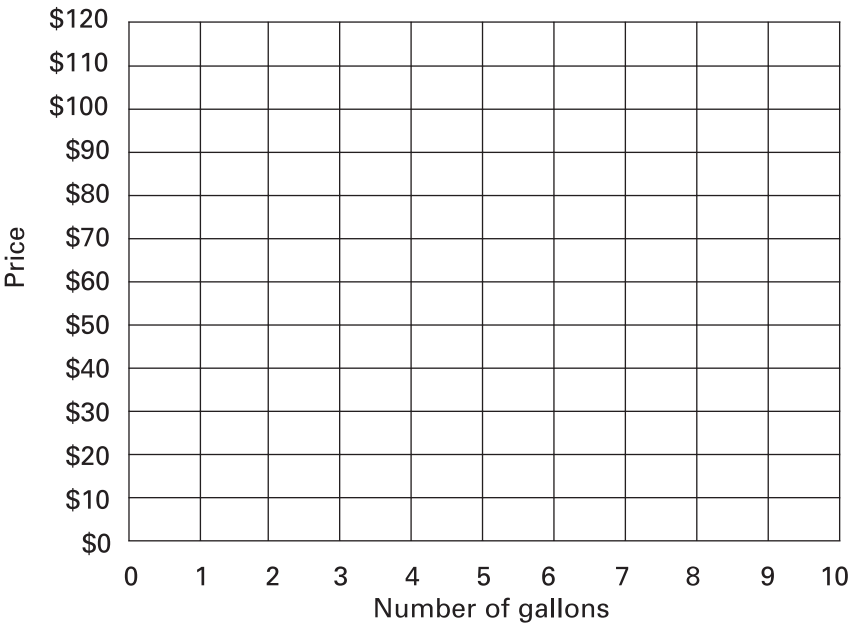
Store	**Paint Price**
Paint Depot	$10 per gallon
Colorful Paint Co.	Buy 3 gallons for $13 each and get one free.
Colors 'R' Us	Buy 1 gallon at $18 and get all additional gallons for ½ off.

	Paint Depot	**Colorful Paint Co.**	**Colors 'R' Us**
1 gallon			
2 gallons			
3 gallons			
4 gallons			
5 gallons			
6 gallons			
7 gallons			
8 gallons			
9 gallons			
10 gallons			

2. Where should you purchase the following amounts of paint?
a) 3 gallons? ______________________________
b) 4 gallons? ______________________________
c) 10 gallons? ______________________________

Junior Architects' Mathematics Tasks—*(continued)*

3. Graph the paint prices.
a) Use three different colors or marks to plot the prices for the three stores. For example, for Paint Depot, use a red pencil to mark a point at $10 for 1 gallon and at $20 for 2 gallons, and so on. Use two different colors to plot the points for Colorful Paint Co. and Colors 'R' Us.



b) Explain the patterns in the prices.

____

c) Which points show that you can buy 4 gallons for the same price as 3 gallons? Explain.

____

Task 2: How many gallons will you need?
4. Assume all the ceiling heights are 10 feet. Using the dimensions of the doors and windows from the blueprint, find the interior wall area of the clubhouse. Remember that the windows and doorways do not get painted.

5. *a)* What is the total area to be painted? __________
b) If each gallon of paint covers 400 square feet, how many gallon cans of paint should be purchased? __________
c) Which store would provide the best buy on the paint? __________
d) How can you tell from the table in problem 1? __________
e) How can you tell from the graph? __________

6. *a)* If the clubhouse requires two coats of paint, how many total square feet will be painted? __________
b) How many gallon cans of paint should be purchased? __________
c) Where should the paint be purchased? __________
d) In general, which store has the best buy? Explain. __________

Task 3: The garden
You have only 20 feet of fencing to create a garden in the backyard. Use a geoboard and inch graph paper to design your garden. How many different rectangular gardens can you make with 20 feet of fencing? __________
Which dimensions will give you the most gardening space? __________
Now create a garden in any shape. Be sure to calculate how much square footage you will have for gardening with your design.