Tiny House, Big Learning

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Abstract: *The authors introduce the Tiny House Project—an interdisciplinary, problem-based Science, Technology, Engineering, Arts, and Mathematics (STEAM) activity. The project was designed to promote the implementation of the Standards of Mathematical Practice (SMP). As 5th graders engaged in the project, they explored the concepts of floor plans, 2-D shapes, parallel and perpendicular line segments, angles, scale drawings, measurement, perimeter, area, 3-D models (using Planner 5D), and spatial reasoning. Moreover, they strengthened their problem solving, planning, and designing skills as they connected measurement and geometry to the real-world context of constructing a house.*

Keywords: *STEAM, Standards of Mathematical Practice, mathematics connections*

1 Introduction

The Standards of Mathematical Practice (SMP) were written to challenge students to develop a mathematical mindset for learning and doing mathematics (CCSSI, 2010). When teachers emphasize these standards, they help their students "see" that mathematics is ever-present in the world around them. This article introduces tasks that promote the implementation of the SMPs in an interdisciplinary and problem-based learning Science, Technology, Engineering, Arts, and Mathematics (STEAM) activity, called the *Tiny House Project* (see Appendix A).

Fifth graders at Bell Creek Intermediate School were challenged to create a tiny house community to help support the homeless population in Dayton, Ohio. Each student was considered an architect. Given the parameter for the overall size of the house, students then had the freedom to use their own ideas, imagination, and mathematical skills to create a unique tiny house. With the aid of technology—Planner 5D (`https://planner5d.com/`)—students were challenged to use multiple measurements and geometric concepts, along with visual spatial reasoning, to plan and construct their tiny house. Specifically, students were asked to complete the following tasks.

a) Create a tiny house with livable space (CCSS.MATH.PRACTICE.MP5);

b) Create a scale model floor plan of a tiny house using appropriate dimensions and square footage (CCSS.MATH.CONTENT.5.NF.B.5, 6.RP.A.1);

c) Measure and label the length of each wall (CCSS.MATH.CONTENT.2.MD.A.1);

d) Calculate the total area (CCSS.MATH.CONTENT.3.MD.C.5.B, 3.MD.C.6, 3.MD.C.7A, 3.MD.C.7B, 4.MD.A.3);

e) Calculate both the perimeter and area of each room (CCSS.MATH.CONTENT.3.MD.C.5.B, 3.MD.C.6, 3.MD.C.7A, 3.MD.C.7B, 3.MD.D.8, 4.MD.A.3);

f) Identify the geometric shape of each room using more than one 2-D shape term (CCSS.MATH.CONTENT.3.G.A.1 and 5.G.B.4);

g) Calculate the cost of flooring (i.e., carpet, tile, or hardwood) (CCSS.MATH.CONTENT.5.NBT.B.7, 6.NS.B.3);

h) Label sets of parallel line segments (CCSS.MATH.CONTENT.4.G.A.1);

i) identify sets of perpendicular line segments (4.G.A.1); and

j) Identify right angles (4.G.A.2).

2 The Tiny House Project

Students were given goals to address the engineering design challenge of generating a tiny house community to help support Dayton, Ohio's homeless population. Along with the floor plan being no more than 120 square feet, design goals included the following:

- One exterior door;
- Two to four single-hung windows;
- A bathroom with a shower or tub/shower combination, sink, and toilet; and
- A kitchen with a sink, stove, and refrigerator.

To illustrate their designs, students were required to create a 2-D floor plan on half-centimeter grid paper and to draw a 3-D model of the exterior of the tiny house (see Figure 1).

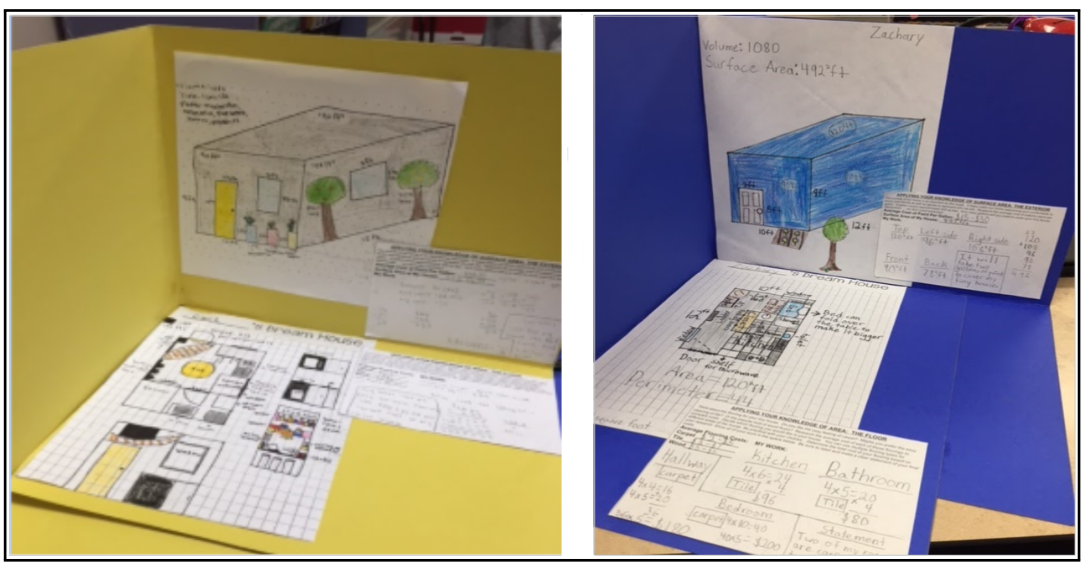

Fig. 1: *Examples of finished student projects.*

2.1 Materials

The materials needed to complete this activity included 0.5 cm grid paper, rulers, and Planner 5D. Some concepts that the students previously explored were properties of 2-D shapes, classifying 2-D shapes, 3-D shapes, classifying prisms, drawing rectangular prisms, area, surface area, and volume. The math and art teacher collaborated previously, and the students had explored perspective drawings of 2-D rectangular prisms and other shapes.

2.2 Engineering Design Process

To complete this project, students were introduced to the engineering design process, which is a series of steps—such as Ask, Imagine, Plan, Create, and Improve—that some engineers follow to come up with a solution to a problem. The process is iterative since engineers often need to go back and repeat a step after learning more information, or they make improvements after failures. Details for each step of the process are as follows.

Step 1: Ask

To introduce students to the project, we asked students the following questions. *What is a tiny house? What does it mean to "live small?" What are essential elements of the living space?* Students were placed in small groups to discuss these questions and to pose new questions that may be pertinent to the design challenge. The whole class then shared their small group discussion results as well as any questions generated in their groups.

Step 2: Imagine

To help students imagine what their tiny house might look like, the class researched various types of tiny houses and investigated websites to become more familiar with what tiny houses are, how they function, and why they are becoming more popular. Students were encouraged to view a video of a 13-year-old who built a tiny house in his back yard (see Figure 2).

Fig. 2: *Video of teenage tiny house builder (available at* `https://tinyurl.com/tiny-house-video`*).*

They were also encouraged to watch short clips from *Tiny House Big Living*, a popular reality TV show on HGTV (episodes are available at `https://tinyurl.com/HGTV-videos`). Students were then asked to find one picture of a tiny house and include the website where the image was found, three facts about tiny houses and how they function, and three reasons people choose to build tiny houses.

This investigation helped students learn about the advantages and disadvantages of living in a tiny house. Advantages included conservation issues like reducing one's footprint on the earth and using less energy to heat, cool, and light; economic reasons like lower cost to build and to heat, cool, and light; and maintenance benefits like reduced time to clean and organize the house, less upkeep, etc. Disadvantages included less privacy and space for those living in the house, lack of storage space, smaller area for entertaining guests, and possible zoning law issues.

Step 3: Plan

Small groups of students discussed what to include in their tiny house. They were given the *Tiny House Project* requirements shown in Appendix A and asked to think about what dimensions they wanted in order for their house to meet the maximum 120-square-feet-of-area requirement. They also considered where to place the door, windows, kitchen sink, stove, refrigerator, bathroom sink, shower or tub/shower combination, and toilet. To make the square footage requirement more concrete and to ensure that all of these items would fit into their house, the class modeled the mathematics by creating a mock 120-square-foot area with masking tape and imagined where they would place each item (MP4).

They used appropriate tools strategically by choosing from rulers, yard sticks, and tape measures to measure the space for their items (MP5). While measuring, they began to create a rough sketch of the 2-D floor plan and recorded the dimensions of each required element. The students attended to precision by reflecting on the questions provided in the project requirements. For instance, *Is your kitchen wide enough to include a stove, sink, and refrigerator and still have enough room for someone to move around and use the space?* (MP6). They also discussed the aesthetics of both the interior and exterior of the house and created an outline of the exterior. See the project requirements for other questions.

To reinforce the concept of calculating area, the *Guess My Room Dimensions* game was introduced. The game encourages the MP of reasoning abstractly and quantitatively (MP2), as students were given the length and area of their classroom and asked to calculate the width of the classroom. For homework, students created three *Guess My Room Dimensions* task cards related to the dimensions of rooms in their tiny house. Using the dimensions of a different room to create each task card, students wrote one word problem for each of the following: 1) the area of one room given its length and width, 2) the width of one room given its length and area, and 3) the length of one room given its width and area (see Appendix A *Guess My Room Dimensions* for sample questions).

The next day, students worked in pairs and traded their first task card, worked to solve the task, and shared their results with each other. They were then required to draw a 2-D model of the room described in the task card, show their work for solving the task, and write an equation to model the scenario (MP4). This process continued as students traded their second and third task cards, and the teacher guided and encouraged the students to communicate precisely, justify their argument, and respond to their peer's arguments (MP3). To extend this task or to differentiate, students were asked to create a fourth task card that required the reader to calculate the width of the room in both inches and feet given the length of the room in feet and the area of the room in inches (CCSS.MATH.CONTENT.5.MD.A.1).

Students were also expected to calculate the cost of the flooring they planned to include. They were given the handout *Applying Your Knowledge of Area: The Floor* (see Appendix A), and prompted to consider the different types of flooring. For instance, *Do you like the cozy feeling of carpet? Or, do you prefer the easy cleaning of tile or the popular look of hardwood floors?* They then researched the cost of each flooring type—carpet, tile, and hardwood—and decided which type of flooring they would include in their house. After determining the total cost of flooring, they shared and discussed with another group of peers their house plans and sketches, including their choice of flooring.

Throughout the planning process, the teacher provided formative feedback to make sure the students' plans addressed the project requirements. This formative assessment consisted of dialogue and questioning with students, along with a simple checklist of the project requirements where verbal feedback was given if the students forgot to address a requirement. Students also sought feedback from other peer groups on livability, functionality, and aesthetics of the houses. While students collaborated and provided advice to each other about their floor plans, they were encouraged to communicate precisely (MP6), construct viable arguments for their home design, and respond to the arguments of their peers (MP3). For example, students were encouraged to ask their peers if the dimensions of a shower or length of a bed were appropriate for an average adult. Students made plausible arguments, taking into account the context of their home design.

Step 4: Create

After an enthusiastic and eventful planning step, students created their 2-D floor plan on centimeter grid paper. The class discussed how to transfer their 2-D rough sketches to the centimeter grid paper, making sure that the dimensions of their house fit on the grid. Students practiced accurately scaling their models and translating them from a rough sketch to a final blueprint. Once the students completed their 2-D floor plans, they drew the exterior of their tiny house. As part of their requirements, the students were tasked with calculating the cost of the paint needed to cover the exterior walls; they completed the handout *Applying Your Knowledge of Surface Area: The Exterior* (see Appendix A). They researched the average cost of exterior paint per gallon. Both the flooring and paint exercises led to an engaging conversation regarding money concepts and skills which could lead to an extension activity in financial literacy. To present their overall project, the students created a miniature replica of their tiny house community, displaying each home as shown in Figure 1. They set up their projects for a gallery walk, which was the culminating event before they transitioned to creating their tiny houses using Planner 5D.

3 Creating a Tiny House with Planner 5D

3.1 What is Planner 5D?

Planner 5D is an online tool to create detailed home plans that include interior design elements such as wall construction and placement, flooring options, and furniture arrangement in both 2-D and 3-D viewing options. The online tool requires no professional skills, and children can work easily with the user-friendly tools. Figure 3 illustrates a sample screen from the software.

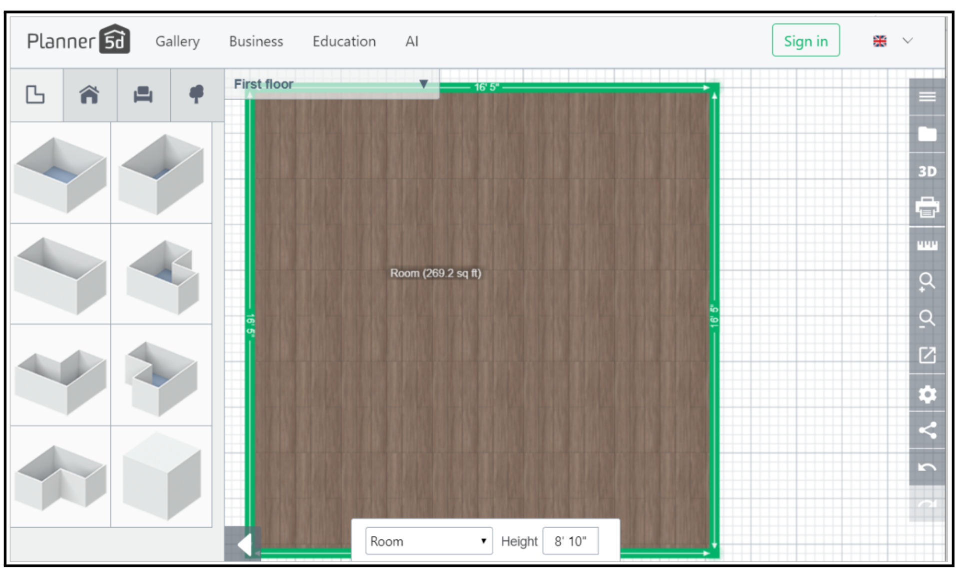

Fig. 3: *The default setting for Planner 5D (available at* `https://planner5d.com/`*).*

3.2 Getting Started with Planner 5D

The students were intentionally given just a brief introduction to Planner 5D, as the teacher wanted them to explore on their own the many options available in this free and user-friendly program (`https://planner5d.com/`). The students accessed Planner 5D on their Chromebooks; it is also accessible on a desktop, laptop, or mobile device. They showed no hesitation in diving in and modeling (MP4) their tiny houses. Students selected *Create a Project* and *Start from scratch*, then viewed five successive slides with information about the program. After reading and exiting from these slides, students' screens showed a 2-D floor plan of a 16′5″ by 16′5″ room with wood floors and the dimensions shown on each wall (see Figure 3).

Students could choose to use metric units instead of standard units by selecting the *Settings* icon in the menu along the right side of the layout area (see the menu in Figure 3), then selecting the *General* tab and toggling to m, cm in the drop-down menu to the right of *Metrics unit*. To change the dimensions of the default room, students dragged a vertical wall to the left or right or a horizontal wall up or down. They renamed rooms by selecting the room, then selecting from the many room names that appeared in the drop-down menu at the bottom of the layout area (see Figure 3).

To create a second room, students selected and dragged to the layout area one of the eight room options in the menu on the left side of the screen (see Figure 3). Although these options appeared in 3-D, only the floor appeared on the layout area when working in 2-D mode. When students wanted to move—or translate—a room, they selected anywhere inside the interior of the room and dragged the room to the desired location.

Students could create an opening between two rooms by selecting the common wall; an image with nine circles/options appeared on the screen (see Figure 4, left). The students enjoyed investigating their options, from splitting the wall into two parts to splitting it into three or four parts. To create an entry between two rooms, students discovered that they could drag the green circle that appeared on the screen after they split the wall into two parts (see Figure 4, right), select the partition that they wanted to remove, and select the circular icon with an eye (see Figure 4, left). The selected section of the wall disappeared! The students quickly figured out that they could make the wall reappear if they selected the missing section of the wall and re-selected the circular icon with an eye.

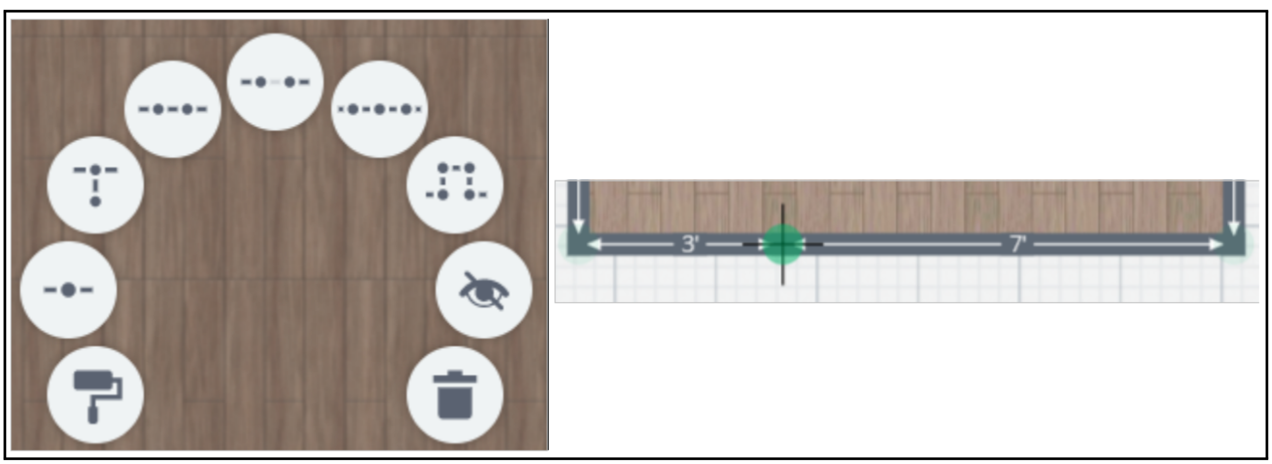

Fig. 4: *(Left) The doorway options menu. For example, select the middle image to create a doorway; (Right) The tool along a wall that is used to change the length of that wall.*

Students were eager to add windows and doors to their project. Some students added windows immediately after creating their first room, while others waited to add them after all of their rooms were complete. To add a window or door, students selected the house icon (highlighted in Figure 5a) from the top left of the layout area to display the *Construction* menu. They selected either the *Windows* or *Doors* option and then selected where in their house they wanted the window or door to appear. The window's width, height, and distance above the floor could be changed by selecting the window and changing the measurement that appeared at the bottom of the layout area (see Figure 5b). Students also figured out how to change the direction a door swings by selecting the door and then selecting the third circular icon (see Figure 5c) and changed whether a door swings into or out of a room by selecting the fourth circular icon.

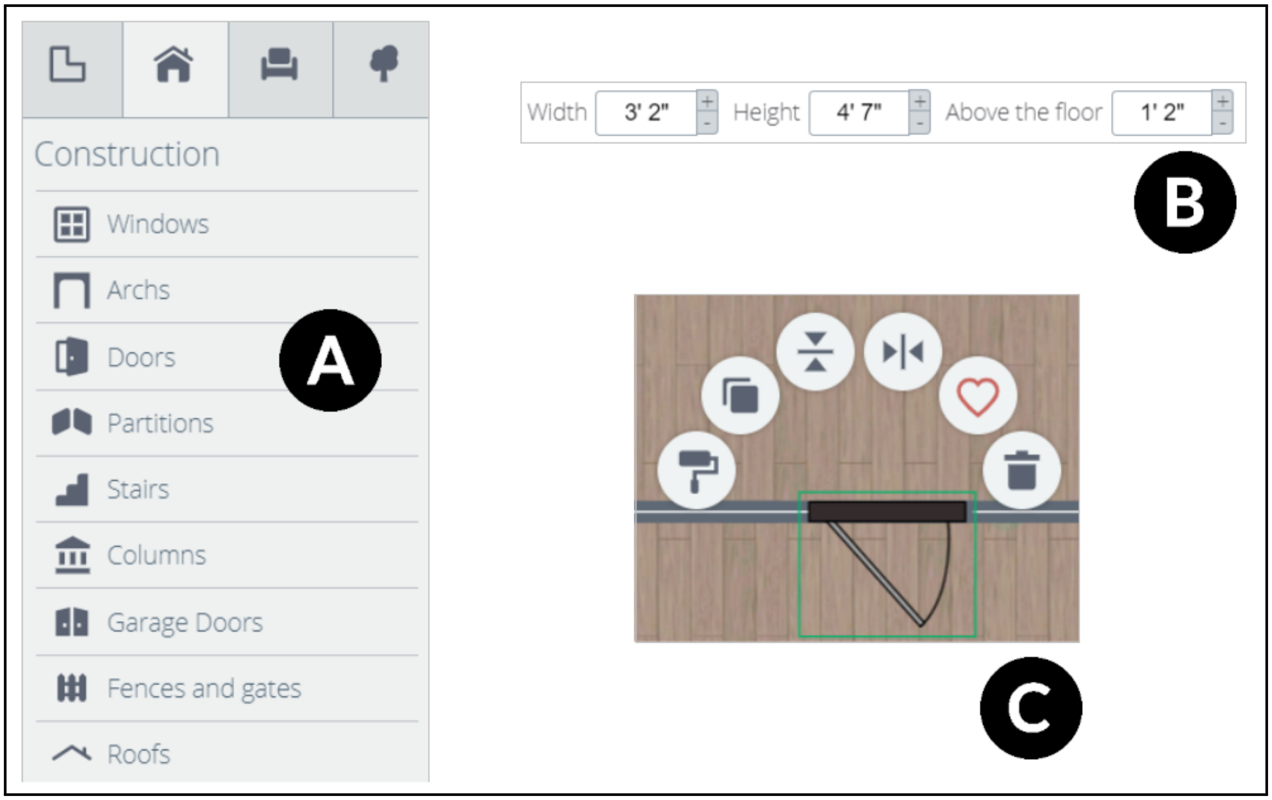

Fig. 5: *(Left-A) The Construction menu; (Right top-B) The width, height, and distance above the floor options for windows; (Right bottom-C) The door options menu.*

Students continued to explore, using their creativity, by choosing from the options for flooring and wall coverings, selecting the furnishings for their house, and adding appliances. To enrich their visualization and spatial skills, students could observe the plan in both 2- and 3-D, as well as change the viewing perspective. They could then extend their imagination by selecting outdoor items, such as a patio, porch, garden, or swimming pool. Figure 6 shows an example of a created floor plan in the 2-D and 3-D format.

Step 5: Improve

To improve their tiny houses, students were asked to maximize storage space and comfort using options from Planner 5D. Students' creativity soared as they explored the various possibilities. They even considered how these changes could affect the cost of building and whether they would be seen as long-term benefits to the home. The students then wrote about these improvements and shared their thoughts within small groups.

Fig. 6: *(Left) 2-D floor plan; (Right) 3-D view of the floor plan.*

4 Extensions to the Tiny House Project

This project has rich potential to be extended to many other areas of content. For example, students could explore circuits and the electrical aspect of building a home. They could research the various jobs that are needed to develop and create a community. They could be asked to generate a marketing and sales plan for their tiny house, or prepare and deliver a multimedia presentation that highlights the tiny house project. There are numerous ways to differentiate these activities, which would serve to further provide real-world experiences for all students.

5 Conclusion

Throughout the *Tiny House Project*, students were asked to complete specific tasks that would enable them to make connections between mathematical concepts—such as geometry and measurement—and to understand how mathematics is embedded in the world around them. For example, students were asked to label the length of each wall to help them calculate the area and perimeter of each room, the total area of the tiny house, and the exterior surface area. They then used area and surface area to calculate the cost of flooring and paint.

The purpose of identifying the two-dimensional shape of each room with more than one classification was to help students further understand that squares, rectangles, rhombuses, and parallelograms share attributes that can define a larger category—namely, quadrilaterals. Identifying the sets of parallel line segments helped students make connections and further their conceptual knowledge that rectangles and squares—found in real-world settings like room sizes—share attributes with parallelograms because they are quadrilaterals with two sets of parallel sides. Encouraging students to identify multiple names for the shape of each room enabled them to think about the hierarchical classification of two-dimensional shapes.

Just as important, the activities in this project emphasize the processes and proficiencies outlined in the Standards of Mathematical Practice. As students worked through the tasks using the engineering design process, they were able to reason abstractly and quantitatively (MP2), construct viable arguments and critique the reasoning of others (MP3), model with mathematics (MP4), use appropriate tools strategically (MP5), and attend to precision (MP6). Students collaborated with others and received constructive and formative feedback from both peers and their teacher. Finally, students were able to create a product using the skills and concepts they learned throughout the project, which they were excited about and proud to share with others. The students experienced how mathematics is ever present in the world around us, and by making connections with other content, they explored problems from a lens that is not only mathematical, but integrated within a larger picture.

References

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APPENDIX A: Student Materials

Tiny House Project

a) Your tiny house must be no more than 120 square feet of area.

b) Your tiny house must be livable: someone must be able to live in your tiny house.

c) Create a floor plan for your tiny house on grid paper.

- Include along the exterior walls the location of the windows and doors.
- Include along the interior walls the location of the doors or doorways.
- Include at least one stove, kitchen sink, refrigerator, bathroom sink, shower or tub/shower combination, and toilet. Label these items in your floor plan.
- Label measurements for each wall. Also, for each item in your floor plan, such as a stove, kitchen sink, couch, table, etc., label its length and width. Reflect on whether or not the length of each wall and the dimensions of each item are appropriate for your tiny house. Ask yourself questions like: Is your kitchen wide enough to include a stove, sink, and refrigerator and still have enough room for someone to move around and use the space? Is your bathroom wide enough for a shower and/or tub, toilet, and sink? Is your shower wide and long enough for a person to move around in while taking a shower? If you include a table, is there enough space around the table for someone to sit in a chair?

d) Calculate the total area of your tiny house.

e) Create a table on a separate sheet of paper with columns for: Room, Shape, Length, Width, Perimeter, Area, and Flooring. For each room in your tiny house, record or calculate the information in your table. Provide two classifications for the 2-D shape of each room. Be creative! Remember to also record the type of floor, which can be ceramic tile, carpet, or hardwood.

f) Calculate the cost of the flooring using the following prices: $4 per square yard for carpet, $7 per square foot for tile, and $10 per square foot for hardwood.

g) Write the letter A beside a set of parallel line segments—the walls—and write the letter B beside a second set of parallel line segments.

h) Locate a line segment that you labeled A that is connected with a line segment that you labeled B. On the backside of your grid paper, write a mathematical term that describes this set of line segments. Also write a mathematical term that describes the angle formed by these two line segments.

i) Draw the exterior of your tiny house. Remember that the exterior of your tiny house is as important as the interior. It helps make your house welcoming and comfortable to family and friends and also serves to represent you!

j) Include the dimensions of each exterior wall along with the surface area of each exterior wall. Finally, include the total surface area of your tiny house.

k) Calculate the cost of paint needed to cover the exterior walls of your tiny house. You will need to research the average cost of exterior paint per gallon. A gallon of paint covers approximately 400 square feet (Remember, we don't paint windows!).

Guess My Room Dimensions

I have included three rooms within my tiny house. I need your help in calculating the dimensions of my rooms so that I can accurately purchase the correct amount of flooring.

a) The main living area of my house has a length of 8 feet and a width of 6 feet. What is the area of my main living area?

b) I don't know the width of my bathroom, but I know it has a length of 8 feet and an area of 32 square feet. What is the width of the bathroom?

c) Finally, I know my kitchen is 40 square feet and that the length is 10 feet, but what is the width of the kitchen?

Applying Your Knowledge of Area: The Floor

Think about the flooring for your tiny house. Do you like the cozy feeling of carpet? Or do you prefer the easy cleaning of tile or the popular look of wood floors? Research the average cost of each of these flooring types and compare the costs. Decide which flooring you would like in your house. You can use multiple flooring types for different areas of the house. Be practical with your choices. Determine the total cost of your flooring based on your research. Show all of your work in the space below. Be sure to label and make a clear statement of your final costs.

Average Flooring Costs:

Carpet _____________

Tile________________

Wood______________

My Work:

Applying Your Knowledge of Surface Area: The Exterior

The exterior of our tiny house is as important as the interior. It helps make your house welcoming and comfortable to family and friends as well as represent who you are. Research the average cost of exterior paint per gallon. A gallon covers approximately 400 sq feet. How many gallons will you need to cover your tiny house? (Remember, we don’t paint windows!)

Average Cost of Paint Per Gallon: _____________

Surface Area of My House That Needs to be Painted: ___________________

My Work: