

I. Lesson 5: Skilled Scaling

How do engineers communicate building designs so that the building is constructed safely and to exact specifications?

Lesson Description:

During this lesson all students will create a blueprint of their Tech Challenge buildings. For grades 4 and 5, students will use straight edges to draw building blueprints in one perspective (side view). Students in grades 6-12 will use straight edges and protractors to draw scaled building blueprints in two perspectives (side and plan view). High school students will also be asked to research the cost of materials and calculate the approximate cost of building their Tech Challenge buildings. *Optional:* Have high school students also draw their scaled building blueprints in front view.

Grade Levels: 4-12

Education Outcomes:

Students will:

- Illustrate their building design using proper engineering drawing techniques.
- Create a scale drawing of their Tech Challenge buildings using unit conversions, multiplication and proportions.

Education Standards

Met: (Note: bolded parts of the standards are fully met by this lesson)

(4) CCSS.Math.Content.4.MD.A.1

Know relative sizes of measurement units within one system of units including km, m, cm; kg, g; lb, oz.; l, ml; hr, min, sec. Within a single system of measurement, express measurements in a larger unit in terms of a smaller unit. Record measurement equivalents in a two-column table.

(7) CCSS.Math.Content.7.G.A.1

Solve problems involving scale drawings of geometric figures, including computing actual lengths and areas from a scale drawing and reproducing a scale drawing at a different scale.

(7) CCSS.Math.Content.NT.7.G.A.2

Draw (freehand, with ruler and protractor, and with technology) geometric shapes with given conditions. Focus on constructing triangles from three measures of angles or sides, noticing when the conditions determine a unique triangle, more than one triangle, or no triangle.

Addressed:

(HS) CCSS.Math.Content.HSG.MG.A.3

Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).

II. Advanced Prep & Set-Up for Lesson

Materials for Lesson Introduction

- Sample engineering blueprints (See Appendix C)
- Protractor (1 per group)
- Yard Stick(1 per group)
- Large white butcher paper or white board

Materials for Engineering Blueprint Challenge

- Pencils (one per student)
- Graph paper (1/4-inch boxes – One sheet per student)
 - free graph paper creator:
<http://www.printfreegraphpaper.com/>
- Rulers & Protractors (one of each per group)
- Model building(s) from Lessons 3 and 4
- Team journals
- Computers/3D modeling software (One per group - for high school students OR students who are generating 3D models of their buildings)

- Sample student engineering blueprints and budget (See Appendix D)

III. Skilled Scaling Lesson Guide

Guiding Questions: How do engineers communicate building designs so that the building is constructed safely and to exact specifications?

A. Lesson Introduction (10 – 15 minutes)

1. Review scale and building to scale. Some talking points and questions might include:
 - In Lesson 4, students scaled up their building models. What did they learn about scale when they did this? Did their larger models perform the same way their smaller models did?
 - What does it mean if we say that something is a “scale model”? (The model has the same proportions but is in a larger scale or smaller scale)
 - What helped students build their scale models with exactly the same proportions of their original model? Did they write, draw or calculate anything in their journals that helped them?
2. Introduce the Engineering Blueprint Challenge. Some of the information you might share could include:
 - A Silicon Valley tech company likes the models that students created and so they are ready to move forward with an **engineering blueprint** for their Tech Challenge competition building.
 - Students will show their engineering blueprint to their Silicon Valley tech company clients and to the City of San Jose who will verify that their buildings are safe and can withstand an earthquake. If their building designs and drawings are clear and aesthetically pleasing, the city will approve their building plans. The quality of these drawings and designs will determine whether or not their project will be approved for construction.
 - At the end of the lesson, students will present their blueprints to a committee to see if their building plans are approved.
3. Discuss engineering blueprints. Use pictures to illustrate your talking points (See Appendix C for Sample Engineering Blueprints). Talking points and questions might include:
 - Looking at all of these examples of engineering blueprints, what do you notice?
 - What do you think engineers use blueprints for? Why might they be important?
 - **Engineering blueprints** are illustrations that explain the dimensions and construction of a product. This could be a blueprint for a computer chip, car, building etc. Blueprints are drawn so that others can easily interpret how to manufacture the good or to explicitly see the design behind a product.
 - Engineering blueprints are used for many purposes including:
 - Helping a client to make design decisions before construction.
 - Demonstrating that the planned design meets city (or other) regulations to get permission to build.
 - Obtaining permits from the city needed before building.
 - Planning all materials that will be needed so that they can be ordered for construction.
 - The most important purpose of an engineering blueprint is to provide a precise plan that the construction crew can use to build the structure. This is particularly important if we want to make sure that the structure will perform as well in an earthquake as the smaller models.

Facilitator Note:

You might play a round of telephone with students. Ask them to notice what happened to the message as it traveled around the circle? Do we end with the same message that we started with? An engineering blueprint must be very clear and accurate, or the structure that is built could look very different from the engineer’s design.

It is important to note that the Engineering drawing samples located in Appendix C are much more complicated compared to what students will be creating. Since grades 4 and 5 will only be asked to draw side views, you may only want to share the side view samples with them. *If you want to show students what they will be drawing, show them the Student Samples in Appendix D.*

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- What might be important to include in an engineering blueprint? What kinds of details do you notice?
- An engineering blueprint must illustrate all sides and components of a structure. It should include a scale and accurate measurements. Labels are also helpful.
- The three different views are:
 - **Plan view (bird's eye view)** – viewing a building from the plan down.
 - **Side view(s)** – viewing a building from each side of the building.
 - **Front view** – viewing a building from the front.
 - *NOTE: For examples of these drawings, See Appendices C and D. For more information about this concept, see vocabulary and content background information section located in Appendix A and Appendix B.*

B. Engineering Blueprint Challenge (50 – 60 minutes)

1. Introduce the Engineering Blueprint Challenge.

Challenge:

Grades 4 and 5: Draw a proportional engineering blueprint of your Tech Challenge model demonstrating the actual size of your building in feet in side view. (See B2 for details)

Grades 6-8: Draw a proportional engineering blueprint of your building converting a smaller model to a full-scale Tech Challenge model that demonstrates the actual size of your building in feet in side and plan view. (See B3 for details)

Grades 9-12: Draw a proportional engineering blueprint of your building converting a smaller model to a full-scale Tech Challenge model that demonstrates the actual size of your building in feet in side and plan view. In addition, calculate the estimated construction cost of your Tech Challenge building. (See B4 for details) *Optional:* Have students also draw their scaled building blueprints in front view.

Criteria

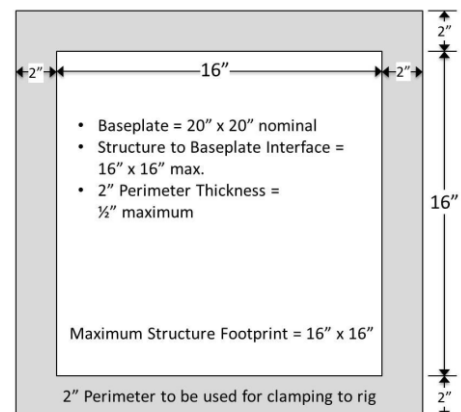
- Show all required views (All grades must include a side view; grades 6-12 must also include plan view.)
- Include all measurements (scaled and actual) with accurate proportions. *This includes angle measurements for Middle and High School students.*
- Must be drawn in the scale of 1 in = 1 foot (for 4th and 5th grade tell them that 4 boxes = 1 foot – for ¼ inch graph paper).
- Have at least 2-3 seismic engineering features labeled (e.g. Dampener, truss, cross bracing etc.)
- Include all structural components
- The blueprint must follow the Tech Challenge constraints (listed below)

Facilitator Note:

There are numerous free 3D modeling programs available on the internet. If you have access to computers, having students model and draw out their buildings in a 3D program could be useful. See *Appendix B* for more information regarding these resources.

Tech Challenge Constraints

- Baseplate must be 20" x 20".
- The bottom of the structure (structure footprint) must be no more than 16" x 16" to allow the device baseplate to be clamped to the rig.
- Above the first 15 inches of the structure base the building may extend beyond the 16" x 16" footprint.
- The height of each story must be at least 5" as measured from floor to ceiling.
- Maximum height of the structure is 6 feet including the baseplate.



2. For elementary school students (4th and 5th grade)

- Students will need to design the size of the building based on the Tech Challenge criteria.
- Have students brainstorm the sizes of each component of their building before they start drawing the actual blueprint. Remind students to use the data that they collected and their physical building models from the previous lessons to inform the design of their buildings.
- Have students brainstorm and sketch their building designs.
- Go over **drawing to scale**. Tell students that drawing to scale allows for engineers and architects to draw their designs on a smaller scale so that they can show their clients the design blueprint before the actual building is built.
 - *NOTE: For more information on drawing to scale, see Appendices A and B.*
- Demonstrate the steps of drawing a sample blueprint. Be sure to cover the following discussion points:
 - Only model how to draw the side view of the building, since this age group will only be drawing the side view of the building.
 - *NOTE: For more information on how to draw the side view of a building, see Appendix B.*
 - 4 boxes on our graph paper equals 1 foot. So how many boxes will you use to draw a 4-foot wide building? (16) Demonstrate this with multiple examples if necessary to ensure student understanding of proportion and scaling.
 - Show students the sample *side view* blueprint (located in Appendix D).
- Once you have modeled how to draw the blueprint, please proceed to Section B.5 of this lesson plan for additional guidance for all grades.

3. For middle school students (6th – 8th grade)

- Students will need to design the size of the building based on the Tech Challenge criteria.
- Have students brainstorm the sizes of each component of their building before they start drawing the actual blueprint. Remind students to use the data that they collected and their physical building models from the previous lessons to inform the design of their buildings.
- Have students brainstorm and sketch their building designs.
- Go over **drawing to scale**. Tell students that drawing to scale allows for engineers and architects to draw their designs on a smaller scale so that they can show their clients the design blueprint before the actual building is built.
 - *NOTE: For more information on drawing to scale, see Appendices A and B.*
- Model how to draw the side view and plan views of the building, since this age group will be drawing both of these perspectives.
 - *NOTE: For more information on how to draw the side view and plan view of a building, see Appendix B.*
 - Tell students that 1 inch equals 1 foot. So, how many inches will you draw a building that is 8 feet tall? (8 inches).
 - If each box is $\frac{1}{4}$ -inch, how many boxes will represent 1 foot? (4).
 - So for an 8-foot tall building, how will you calculate the number of squares that will represent the height? (4 boxes to one inch multiplied by 8 inches = 32 boxes)
 - Show students the sample *side view and plan view blueprint* (see Appendix D).
 - Students will need to use rulers and protractors to draw their buildings. This is so that their blueprints can be accurate enough for them or for someone else to recreate their building later.
 - Model conversion of ruler measurements from previous building models. For example, if a model is 4 feet tall and they now want to make it 8 feet tall, then the floors will be roughly double their model. If one floor is 6 inches, in the new building this would be 12 inches or 1 foot in the new building represented by 4 squares. Demonstrate this with multiple examples if necessary to ensure student understanding of conversion.
 - Model how to use a protractor to measure any angles that are not 90 degrees on the cross bracing of one group's model and to then draw in the cross bracing with this same angle on the blueprint. Discuss the importance of replicating these angles exactly, so that teams can ensure similar results when shaking their larger buildings.

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▪ *NOTE: For more information on protractor use, see Appendices A and B.*

- Once you have modeled how to draw the blueprint, please proceed to Section B.5 of this lesson plan for additional guidance for all grades.

4. For high school students (9th – 12th grade)

- Students will need to design the size of the building based on the Tech Challenge criteria.
 - Have students brainstorm the sizes of each component of their building before they start drawing the actual blueprint. Remind students to use the data that they collected and their physical building models from the previous lessons to inform the design of their buildings.
 - Have students brainstorm and sketch their building designs.
 - Go over **drawing to scale**. Tell students that drawing to scale allows for engineers and architects to draw their designs on a smaller scale so that they can show their clients the design blueprint before the actual building is built.
 - *NOTE: For more information on drawing to scale, see Appendices A and B.*
 - Model how to draw the side view and plan views of the building, since this age group will be drawing both of these perspectives.
 - *NOTE: For more information on how to draw the side view or plan view of a building, see Appendix B.*
 - Tell students that 1 inch equals 1 foot. That means that for an 8 foot tall building, on the blueprint, the building will be drawn 8 inches high.
 - Show students the sample *side view and plan view blueprint* (see Appendix D).
 - Students will need to use rulers and protractors to draw buildings that are proportional to their smaller building model. This is so that their blueprints can be accurate enough for them or for someone else to recreate their building later and to try to replicate the aspects of their design that were successful in their smaller models.
 - Review how to use a protractor to measure any angles that are not 90 degrees on the cross bracing of one group's model and to then draw in the cross bracing with this same angle on the blueprint. Discuss the importance of replicating these angles exactly, so that teams can ensure similar results when shaking their larger buildings.
 - *NOTE: For more information on protractor use, see Appendices A and B.*
 - Discuss team budgets or cost analyses. (See Appendix D for a sample budget).
 - Students will need to determine the cost of the materials needed to build their buildings.
 - Have students research the cost of desired materials and estimate the cost of building their Tech Challenge building based on the sizes they've calculated in their blueprints.
 - Have students complete this cost analysis in their engineering journals.
 - Have students reflect on the cost of the building and ask them if there are cheaper and more efficient ways to build their Tech Challenge buildings. It might also be useful to have students justify their reasoning and why they are using certain materials.
 - To calculate approximate cost of construction have students follow this process:
 1. List all of the materials and sizes needed
 2. Find the cost of materials.
 - a. For items that are priced by length, have students find the price per length and multiply accordingly.
 - b. Be sure to remind students to multiply cost for using multiples of the same item.
 3. Add up the cost of all materials to find the total materials cost.
 - Once you have modeled how to draw the blueprint and cost analysis, please proceed to Section B.5 of this lesson plan for additional guidance for all grades.
5. While students are drawing/designing their buildings, ask any/all of the following questions:
- What are some features that make your building safer during an earthquake? How do you know that these parts of the building will make it safer during an earthquake?
 - Why do you think engineers draw to scale? How is your drawing to scale?
 - Ask students about a specific part of their building and ask how many inches that part of the building is. Then ask how long that part will be when they actually build the building. Ask them for their reasoning.

C. Blueprint presentation preparation (20 – 30 minutes)

1. Introduce the Blueprint Presentation.
 - Students will need to present their blueprints to a “committee” in order to obtain their building permits.
 - Go over the presentation guidelines listed below.

Criteria

- Must explain all parts and design components of the building
- Must justify seismic design by using data from the previous lessons.
- Must show/present/display their seismic blueprints

Constraints

- Students will only have 3 minutes to present

D. Blueprint presentations (50 – 60 minutes)

1. Go over audience norms with the students.
2. Tell audience members that they are part of the permit committee. To do this, the audience members will be asked to provide feedback to each group on how well their blueprint meets the Tech Challenge criteria and suggestions for improvement as they also prepare to present to judges at The Tech Challenge.
3. Audience members should consider the following questions as they listen:
 - Did all group members present and clearly explain the features of the building that make it seismically strong?
 - Does the building meet The Tech Challenge criteria and constraints?
 - Do you think you could construct this building using the blueprint that the group is presenting?
4. Have the first group present. Once the group has finished presenting, ask the audience members for key feedback on :
 - What did each group do well that will help them to be successful at The Tech Challenge?
 - What might they need to think about that will help them to improve at The Tech Challenge?

Facilitator Notes:

Some suggested audience norms are: One person speaking at a time, no questions until the end of the presentation, no side conversations, be supportive etc.

It is important to remind students that some people have harder times presenting than others. Encourage them to be supportive and caring when listening to their peers.

It might be helpful to write the key vocabulary words on the board so students can refer to them while they prepare the presentations.

It might also be helpful to write the three committee questions on the board so that students can refer to them during the presentation.

E. Debrief (10 – 15 minutes)

1. Have students reflect and share out on their designs. Some possible questions to ask are:
 - Why is it important for engineers to draw accurate engineering blueprints?
 - What makes an engineering blueprint clear and easy to follow?
 - What is useful about each type of view?
2. Congratulate students on completing their design challenges. Give one or two pieces of positive feedback. Support students to build their Tech Challenge buildings so that they can compete in the Tech Challenge.

IV. Appendices

A. Vocabulary

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- **Engineering blueprint** – Illustrations that explain the dimensions and construction of a product. This could be a blueprint for a computer chip, car, building etc. Blueprints are drawn so that others can easily interpret how to manufacture the good or to explicitly see the design behind a product.
- **Plan view (bird's eye view)** – viewing a building from the plan down.
- **Side view(s)** – viewing a building from each side of the building.
- **Front view** – viewing a building from the front.
- **Corner view** – viewing a building in three dimensions. This perspective is gained if the building is drawn as if someone is looking directly at the vertical edge (the edge that runs the entire height of the building).
- **Drawing to scale** – A scale drawing is proportional to the actual size of the building. For example, someone could draw a 1000 foot skyscraper on a piece of paper by drawing it at 1/500th of the size.

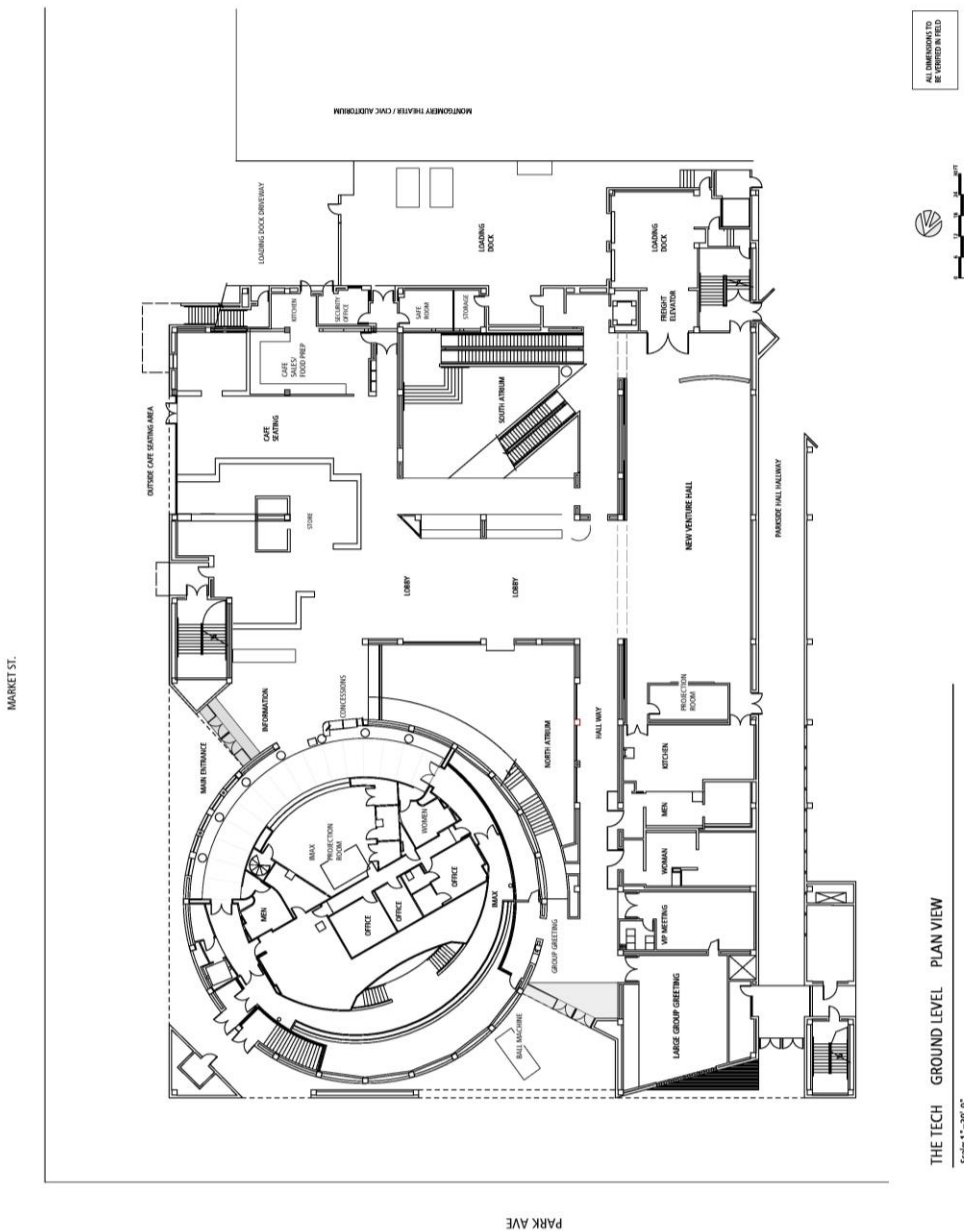
B. Content Background Information Section

<i>More information on engineering drawing</i>	http://www.ehow.com/list_6731910_engineering-drawing-methods.html AND/OR http://www.ehow.com/about_6722022_engineering-drawing-techniques.html	Gives examples of engineering drawings and explains different ways to construct engineering blueprints. This is to be used by facilitators who would like more content background knowledge on the subject.
<i>How to use a protractor</i>	http://www.mathsisfun.com/geometry/protractor-using.html	Explains how to use a protractor. Has step by step instructions and online practice problems.
<i>How to convert inches to feet</i>	http://www.wikihow.com/Convert-Inches-to-Feet	Explains how to convert inches to feet.
<i>How to draw to scale</i>	http://www.basic-mathematics.com/scale-drawings.html	Explains how to draw to scale. Gives step by step directions and examples.
<i>How to draw side view (elevation) and plan view</i>	http://alittledesignhelp.com/what-is-an-elevation-drawing/ AND https://www.youtube.com/watch?v=Bvc_gYHlgJs	The first link shows how to draw the side view of a wall/building. The second link shows how to draw in three different perspectives and emphasizes on drawing a plan view (bird's eye)
<i>Free 3D modeling online resource</i>	http://www.sketchup.com/	Free to download. Easy to use. Will take some practice.

C. Sample Engineering Blueprints for Lesson Discussion Section A.2 (Drawings not to scale)

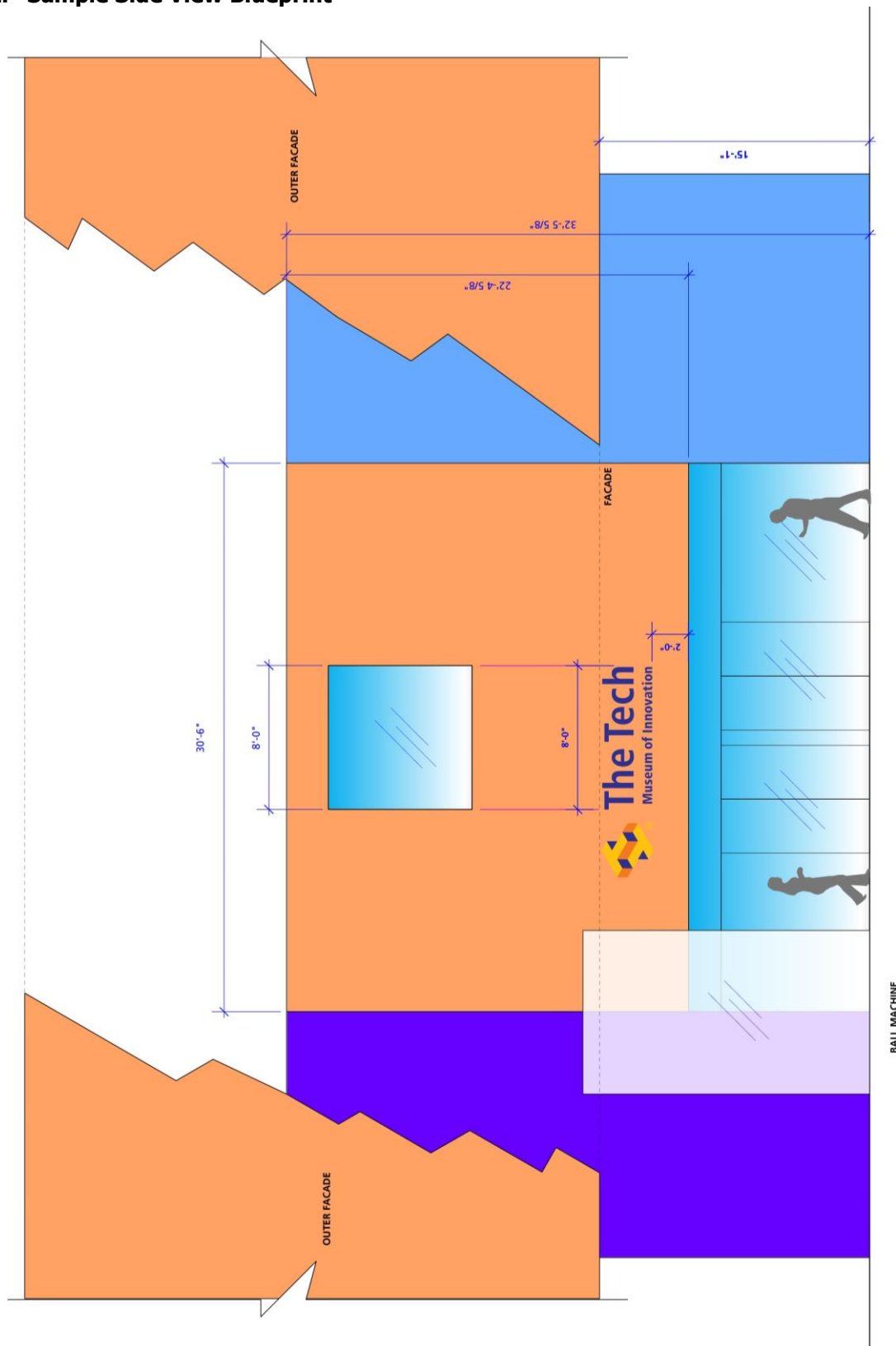
1. Sample Plan View Blueprint

	201 South Market Street San Jose, CA 95113	145 West San Carlos Ave San Jose, CA 95113	Scale: AS NOTED By: Project Team Date: 06 AUG 2014 Notes:	THE TECH MUSEUM GROUND LEVEL 2014	Copyright 2014 The Tech All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or by any information storage and retrieval system, without the prior written permission of The Tech.	Ex 00.02
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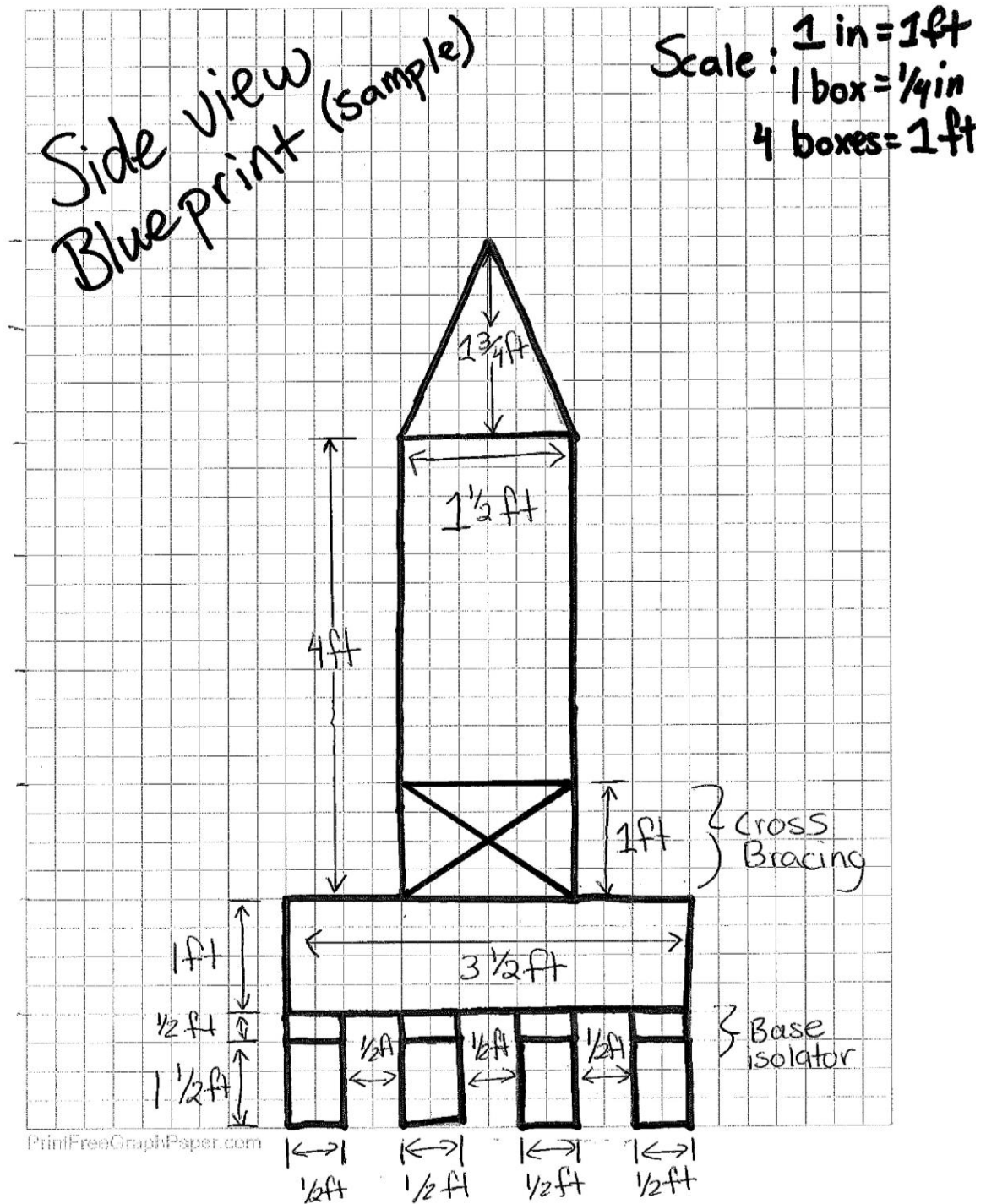
THE TECH GROUND LEVEL PLAN VIEW
 Scale: 1"=30' 0"

2. Sample Side View Blueprint

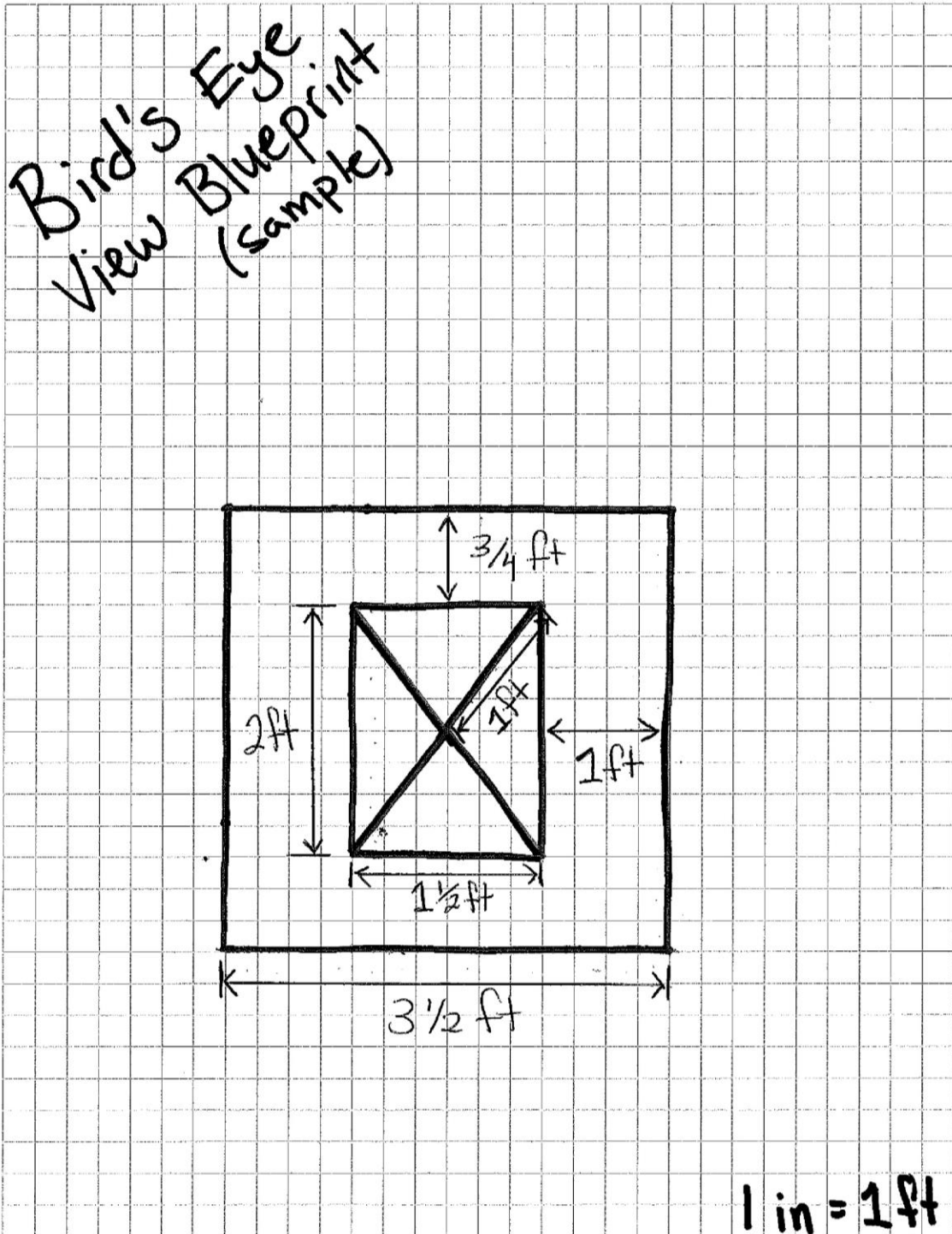


3. Sample Complex Plan View Blueprint

1. Student Sample Side View Blueprint



2. Student Sample Plan View Blueprint




PrintFreeGraphPaper.com

Scale: 1 box = 1/4 in
4 boxes = 1 ft

3. Student Sample Budget

SAMPLE Budget for High School

Material	Quantity Needed	Cost per unit	Total Cost
Wood ($\frac{1}{2}$ in thick)	8 feet	.10¢ per foot	.80¢
Glue sticks	10	.50 per stick	\$5
Screws	50	\$10 per box of 50	\$10
Nails	10	\$2 per box of 20 (smallest amount we can buy)	\$2
		Grand Total w/out tax	\$17.80

E. References

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