Spatial Visualization

Workshop 1: Orthographic Views

Overview

Grade level: undergraduate engineering students

Estimated time required: 2 hours

Expendable materials: orthographic paper printouts, scrap paper and pencils

Reusable materials: workbooks, software, computers, snap cubes (used for all workshops), blindfolds. *See Materials List (below) for details.*

Summary

Students learn how to create two-dimensional representations of three-dimensional objects by utilizing orthographic projection techniques. In a four-station workshop structure, students rotate through different group-oriented activities that call on various learning styles to solidify the concept. Students use cube blocks to build 3D models and then draw orthographic views of those shapes, which are the three side views—top, front, right—with no depth indicated. Next, they individually practice workbook problems and check their answers. Then, working in pairs, one blindfolded partner describes a multi-cube shape by feel as the other partner draws what is described. Lastly, online activities provide additional practice and concept explanation.

Engineering Connection

Orthographic projection is a useful skill for engineers that helps them take ideas that only exist in their minds and create visuals in order to communicate with other engineers. Orthographic views are especially helpful for detailing manufacturing and construction designs. Mechanical engineers provide orthographic drawings of parts to machinists for fabrication. Civil engineers provide orthographic drawings of structures to construction crews. Orthographic drawings depict objects from multiple perspectives (top, front and side). The combination of these views help to make sure that components can be accurately created in accordance with engineers' requirements.

Pre-Requisite Knowledge

Students should be familiar with the Cartesian coordinate system and its x-, y- and z-axes. The instructor may want to administer a spatial visualization test such as the *Purdue Spatial Visualization Test: Rotations* (PSVT:R) as a pre-test to establish student skill baselines, and then administer the same test after the seventh lesson/workshop in this series as a post-test to measure learning and skill gains.

Learning Objectives

After this workshop, students should be able to:

- Explain the concept of orthographic projection and how it is useful in engineering.
- Draw the three principle orthographic views of an object.
- Provided with the principle orthographic views, visualize and build the object.

Materials List

Item	Description & Amount	Source/Supplier/Cost	Station #s
Orthographic paper	For sketching, 2+ per student	Orthographic Paper (pdf); print double-sided as needed	1, 2, 3
Snap cubes	Interlocking cubes, 8 cubes per student	Such as: Higher Ed Services ($3 for 15 cubes) or Amazon ($85 for 200)	1, 3
Pencil with eraser	Any erasable pencil; pens are not recommended	School/students provide	1, 2, 3
Colored pencils	To associate drawings to the snap cubes; to share among all students	Such as: Crayola colored pencils at Amazon ($8 for 50)	1, 3
Blindfolds	To prevent students from seeing an object	Standard bandanas work well	3
Developing Spatial Thinking *Workbook & Instructional Software*	1 per student pair; includes web-based software used with workbook	$40 for workbook/software from Higher Ed Services	2 (workbook) 4 (software)
Computer or laptop	1 per student pair	School/students provide	4
Workbook answers	For the instructor and for students to check their work	Workbook Answer Key (pdf)	2
PowerPoint® presentation	For the instructor, slides 1-11	Spatial Visualization Presentation (pptx)	NA

Introduction & Motivation

Have the slide presentation up and displayed to the class, starting with slide 1. The slides are animated, so a mouse or keyboard click brings up the next graphic or text. In as much detail as you like, review the overall workshop topics and the value in developing spatial visualization skills. Then move on to slide 2.

In this lesson, we will learn about orthographic drawings and their importance in engineering.

Display slide 3.

Orthographic drawings are two-dimensional depictions used to describe three-dimensional objects. Essentially orthographic drawings—also called multi-view drawings—are the projection of a 3D shape onto a 2D surface. Because depth is not shown, projection is sometimes described as "pancaking" the object against a board or wall, or as the silhouette or shadow of a tall building. The views represent the exact shape of an object as seen from one side at a time as you are looking perpendicularly to it.

Display slide 4.

An orthographic view is a way to draw an object that shows three views of the object from the three planes in an orthogonal (right-angle) coordinate system. The three primary orthographic views used to describe an object are top, front and right side. For example, when describing a skyscraper, an engineer might say, "the front and sides of the building are glass, while the top of the building is all steel." This is an orthographic description that could potentially be turned into an orthographic drawing of the building.

Show slide 5, which is the same as Figure 1.

The three orthographic views are defined by using a Cartesian coordinate system with three different planes: x-z plane, x-y plane and y-z plane. The top view is looking "down" the y axis into the x-z plane, the front view is looking "down" the z axis into the x-y plane, and the right-side view is looking "down" the x axis into the y-z plane.

In this figure, the three orthographic views of the object are shown to the right of it. Notice that the top and front views are the same width, while the front and side views are the same height.

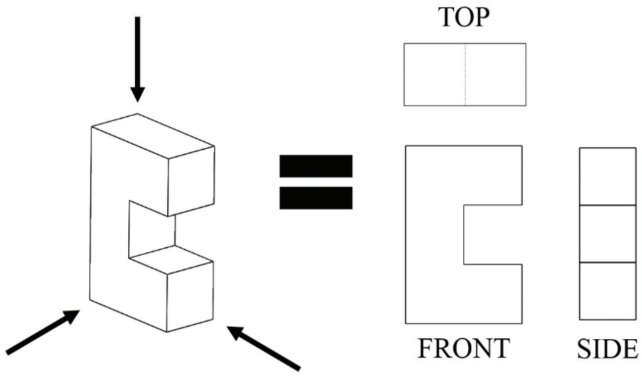

Figure 1. *The three main orthographic views of an object: top, front and side.*

Display slide 6 and then slide 7.

Orthographic views should always be drawn in the same arrangement as what you see here, so that the three views are aligned. The organized alignment helps us visualize the object more easily. ***Move to slide 8 to show a few more objects and their orthographic drawings.***

Show slide 9, drawings of a bench and a church.

Orthographic views can be provided for more than just the average blocky shape. In fact, engineers make them for about everything they create. The plans shown here for a bench and church are real-world engineering examples of orthographic drawings that are necessary in the design and construction of everyday objects and structure.

Introduction & Motivation Continued

At this point, expect students to have a solid grasp of the concept of orthographic views and their value, so move on to explain how they are drawn. Use slide 10 to teach the orthographic drawing process. If your technology permits, such as by using PowerPoint on a tablet computer, use the orthographic paper on the right side of the slide to draw the orthographic views of the shape on the left. Do this in order of top, front and then side, following the view arrangement shown in previous slides. Go through the drawing tips.

Edges are defined as a change in depth on the surface plane and are represented by solid lines. Hidden edges may exist; they are components of the object that may be hidden from the specific view being drawn, but still represent a change in depth within the surface plane. In your drawings, represent hidden edges by dashed lines. In cases in which a seen edge is in the same location as a hidden edge, a solid line trumps a dotted line.

Slide 11 recaps the four workshop stations. Leave slide 11 up so students know what to accomplish at each station.

Vocabulary

Term	Definition
edge	A change in depth on the surface plane that is represented by a solid line.
front view	The two-dimensional depiction of an object from the z-axis perspective.
hidden edge	A change in depth within the surface plane that may be hidden from the specific view being drawn. Represented by a dotted line.
orthographic view	A way to draw an object that shows three views of the object from the three planes in an orthogonal (right-angle) coordinate system. The views represent the exact shape of an object as seen from one side at a time as you are looking perpendicularly to it. Depth is not shown. An orthographic drawing is also called a multi-view drawing.
projection	The process of mapping 3D points onto a 2D plane. For example, imagine the silhouette or shadow of a tall building.
side view	The two-dimensional depiction of an object from the x-axis perspective.
top view	The two-dimensional depiction of an object from the y-axis perspective.

Lesson Procedure

Before the Workshop

- Gather materials.
- Make copies of the Orthographic Paper. Print double-sided to reduce paper use and increase drawing area.
- Prepare a way to digitally get students the web-based software link they will need for this lesson such as by email or by preparing a workshop website with the link.
- Prepare to project the Spatial Visualization Presentation, a PowerPoint® file, and use its content to aid in your instruction, as makes sense for your class. Slides 1-11 support this lesson. The slides are animated so a mouse or keyboard click brings up the next graphic or text.
- Prepare the four stations, as described in slide 11 and Figure 2.

Station 1: Block Relay

- Build an object with 8 blocks
- Draw the **three orthographic views**
- Then pass the object to a neighbor and repeat
- Check drawings for accuracy with neighbor

Station 2: Workbook Drill

- Individually, answer questions on **ODD** pages ortho1 to ortho24 on scrap paper
- Check your answers with the answer key

Station 3: No-Look Pass

- In pairs, one student wears a **blindfold** while the other student builds an object with 5 blocks
- The blindfolded student holds the object and describes the **three orthographic views** out loud
- The partner draws ONLY what is described by the blindfolded student
- When finished, correct the drawing and switch roles
- Repeat and practice, moving to larger objects

Station 4: Computer-Aided Visualization

- Read *Module 4 - Orthographic Views*
- Complete the **orthographic views** exercises

Figure 2. *The four stations for Workshop One.*

With the students: Introduction

- Present to the class the Introduction & Motivation content, supported by slides 1-11.
- Divide the class into four groups that will rotate through the four stations.
- Give each student 2 pieces of orthographic paper and 8 cubes.
- Explain that students are to apply the orthographic drawing methods they just learned as they work through the four stations.
- Direct students to work on one piece of orthographic paper until it is full.

Lesson Procedure Continued

Station 1: Block Relay

Students begin by each building an object with the eight snap cubes. Then they draw the three orthographic views of the object, in the alignment described earlier. Once drawings are complete, students trade objects with a neighboring student and repeat the process with that shape. When both students are done, they compare drawings and evaluate them for accuracy. Expect drawings to look like the example in Figure 1 and follow the drawing tips in slide 10.

Station 2: Workbook Drill

Have students individually answer the workbook questions on odd pages ortho1 to ortho24, recording their answers on scrap paper. After they have completed the problems, have them check their answers with the answer key. Then have them communicate with neighboring students about answers they may have gotten wrong and collaborate on ways to understand and solve the problems.

Station 3: No-Look Pass

In pairs, one student wears a blindfold while the other builds an object with 5 snap cubes. The blindfolded student holds the object and describes the three orthographic views out loud. Listening closely, the partner draws only what is described by the blindfolded student. When finished, students check for accuracy, correct the drawing and switch roles. As the pairs get more practice, have them make larger objects. If students struggle with their drawings, refer to the slide 6 example (same as Figure 3).

Station 4: Computer-Aided Visualization

Have students individually read *Module 4 - Orthographic Views* from the *Developing Spatial Thinking Software* and complete all orthographic views exercises.

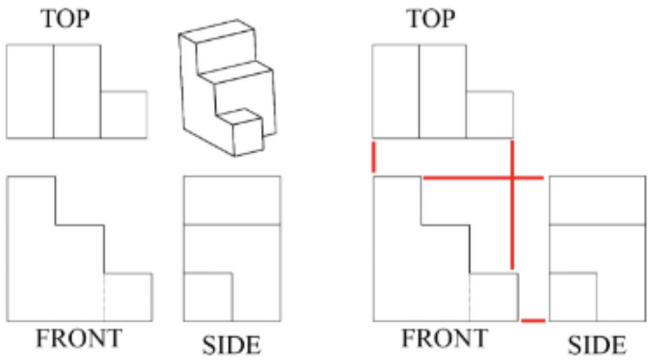

Figure 3. *The top, front and side views of a 3D object. Notice that the top and front views are the same width, while the front and side views are the same height.*

Instructor Tips

When students first begin drawing orthographic views, expect some to be unclear about what is meant by an "edge." Suggest that they physically touch the *changes in plane* on the objects they built and reiterate with them that these are edges. Ask them to describe them out loud.

When first taught, hidden edges can be extremely confusing. If students struggle:

- Use physical demonstrations to explain them.
- Have students intentionally build multi-colored snap cube objects with a hidden edge to solidify the concept.
- Have them use colored pencils to add color to their drawings that coordinate to the multi-colored objects as a way to differentiate surfaces, edges and hidden edges.

For students who need a challenge:

- Have them make and draw 8-cube objects composed of the *same-color* cubes. Just as different colors make the edges pop, the reverse is also true.
- Flip the process: Provide an orthographic drawing and have them build the object.

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