ENGINEERING DRAWING

Module 4: Volume and Surface Area

Teacher Facilitation Guide

Grade: 6th–8th

Duration: ~1 Week (5 Class Periods)

Module Overview

In Modules 1, 2, and 3, students built vocabulary for 3D objects, explored nets and unfolding, and learned to communicate 3D designs using 3-view drawing. In Module 2, they built and unfolded cube nets — discovering that a net contains all the faces of a 3D object laid flat. In Module 4, students return to that idea: counting the squares in a net is the same as counting the exposed faces of the structure, which is the same as calculating surface area. Students use nets as a face-counting scaffold alongside their 3-view drawings to calculate volume and surface area, and connect these measurements to real engineering decisions.

BY THE END OF THIS MODULE, STUDENTS WILL BE ABLE TO:

- Explain the difference between volume and surface area in their own words
- Calculate the volume of a cube structure by counting unit cubes
- Calculate the surface area of a cube structure by counting exposed faces
- Use 3-view drawings as a tool for counting and calculating
- Connect volume and surface area to real engineering design decisions

MATERIALS

- Wooden cubes (1" size) — pre-built stations and/or student cubes
- Graph paper, pencils, rulers
- Station recording sheet (see template in this module)
- Handout 1 — Student Recording Sheet

MODULE STRUCTURE

- Activity 1 — What Are Volume and Surface Area? (1 day)
- Activity 2 — Station Rotations (2 days)
- Activity 3 — Drawing + Calculating (1 day)
- Activity 4 — Design Connection and Reflection (1 day)

Standards & Learning Goals

Standard	Details
Georgia Standards of Excellence	Grade 6: EET-1, EET-7 | Grade 7: II-3, II-7 | Grade 8: TS-2, TS-7
NGSS Standard	MS-ETS1: Engineering Design MS-PS1: Matter and Its Interactions https://www.nextgenscience.org/dci-arrangement/ms-ets1-engineering-design
Performance Expectation	MS-ETS1-1: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. MS-ETS1-2: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. Common Core Mathematics: 6.G.A.2 — Find the volume of a right rectangular prism with fractional edge lengths by packing it with unit cubes. 6.G.A.4 — Represent three-dimensional figures using nets made up of rectangles and triangles, and use the nets to find the surface area of these figures.
Common Core Math 6.G.A.4	Represent three-dimensional figures using nets made up of rectangles and triangles, and use the nets to find the surface area of these figures.

Learning Dimension	Classroom Connections
Science and Engineering Practice *Using Mathematics and Computational Thinking:* Students use counting strategies to calculate the volume (cubic units) and surface area (square units) of cube structures. They apply these calculations to evaluate design trade-offs — recognizing that the same volume can be achieved with different configurations that have different surface areas.	In Activity 1, students count unit cubes to calculate volume and count exposed faces to calculate surface area across multiple station structures. In the design connection activity, students use these calculations to reason about material efficiency, packaging constraints, and other engineering considerations.
Disciplinary Core Idea 6.G.A.2: Volume of Right Rectangular Prisms Students extend their understanding of volume from simple rectangular prisms to irregular cube structures by treating each 1-inch cube as a unit of volume. Counting unit cubes directly connects the geometric concept of volume to the physical cube structures students are building and drawing. 6.G.A.4: Surface Area Using Nets Students connect the idea of 'unfolding' a 3D shape to the 3-view drawing convention from Module 3. Counting exposed faces from all 6 views provides a systematic method for calculating total surface area — directly linking engineering drawing skills to mathematical measurement.	Students count unit cubes in pre-built station structures to determine volume, then count exposed faces view by view (Top, Front, Right, Bottom, Left, Back) to determine surface area. The station rotation format provides repeated practice with structures of varying complexity. The 3-view drawing serves as a calculation scaffold — students use their drawings to organize their face counts systematically.
Crosscutting Concept *Scale, Proportion, and Quantity:* When physical objects are represented in 2D drawings drawn to scale, properties such as surface area and volume can be determined from those drawings. Students explore how changes in shape — while holding volume constant — affect surface area, developing proportional reasoning about 3D structures.	In Activity 1, Part 3, students rearrange a fixed number of cubes into different configurations and observe that volume does not change while surface area does. This builds the insight that shape matters in engineering design: a compact structure has less surface area (less coating material needed) while a spread-out structure has more surface area (more heat dissipation, more exposure).

Engineering Skill Learning Goals

- Students use engineering drawings and physical models to calculate volume and surface area of 3D structures.
- Students connect mathematical measurements (volume, surface area) to engineering design decisions — including material use, packaging, and structural trade-offs.
- Students investigate how changing the shape of a structure (while keeping volume constant) affects its surface area.
- Students communicate design reasoning that uses volume and surface area as constraints or evaluation criteria.

Key Vocabulary

These words are introduced in Module 2 and carry forward into Modules 3 and 4. Reinforce vocabulary from Module 1 (face, edge, vertex) as these activities build on those concepts.

Term	Definition
Volume	The amount of space a 3D object takes up. For cube structures, we count the number of 1-inch cubes. Units: cubic inches (in^3).
Cubic Inch (in^3)	The unit for measuring volume in a cube structure. One cubic inch = 1 in × 1 in × 1 in — it measures 3 dimensions.
Surface Area	The total area of all the outside faces of a 3D shape. For cube structures, we count all the exposed (outside) faces. Units: square inches (in^2).
Square Inch (in^2)	The unit for measuring surface area. One square inch = 1 in × 1 in — it measures 2 dimensions (a flat face).
Exposed Face	A cube face on the outside of the structure — not hidden or touching another cube. Only exposed faces count toward surface area.
Unit Cube	A single cube with edges of 1 inch. Each unit cube in a structure has a volume of 1 cubic inch.

ACTIVITY 1

Introducing Volume and Surface Area

Essential Question: How can we use cube drawings to measure the space an object takes up and its outside area?

TIME
~45 min

Opening — Connect to Real Life (10 minutes)

Discussion: Why Do These Measurements Matter?

Volume — How much space does it take up?

- *"If you are packing boxes to move, you need to know if everything will fit in the truck. That's volume."*
- *"If you are making a fish tank, you need to know how much water it will hold. That's volume."*

Surface Area — How much outside area does it have?

- *"If you are wrapping a birthday present, you need enough wrapping paper to cover the whole outside. That's surface area."*
- *"If you are painting a wall, you need to know how many square feet to paint. That's surface area."*

Part 1 - Introducing Volume — Counting Cubes (10 minutes)

What is Volume?

Volume is how much space a 3D object takes up. For a structure made of 1-inch cubes, the volume is simply the number of cubes in the structure.

Example: A structure made of 5 cubes has a volume of 5 in^3.

Why cubic inches? Volume measures 3D space, so we need three dimensions. Each cube is 1 in × 1 in × 1 in = 1 in^3.

Have students build structures of a given volume (4 in^3, 8 in^3, etc.). Guide them to notice that they may build different structures that have the same volume.

TEACHER NOTES

Scaffolding hidden cubes

Tricky situation: What if a cube is hidden on the inside of a structure? Students need to count it for volume even though they cannot see it.

Strategy: Build the structure layer by layer. Count the cubes in each layer separately, then add all the layers together.

Part 2 - Introducing Surface Area — Counting Faces (15 minutes)

What is Surface Area?

Surface area is the total area of the outside faces of an object. For 1-inch cube structures, each exposed face has an area of 1 in^2. Count only the exposed faces — faces touching another cube do not count. In Module 2, students built cube nets and discovered that a net includes exactly all the exposed faces of a structure laid flat. The area of that net is the surface area. Students can use this connection as a strategy: imagine unfolding the structure into a net and count the squares.

Why square inches? Surface area is flat (2D), so we measure in square inches (in^2). Each face is 1 in × 1 in = 1 in^2.

> Walk through a 2-cube example together:
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> - Two separate cubes would have 6 + 6 = 12 faces.
> - When pushed together, 2 faces get hidden (where they touch). So: 12 − 2 = 10 exposed faces.
> - Surface area = 10 in^2

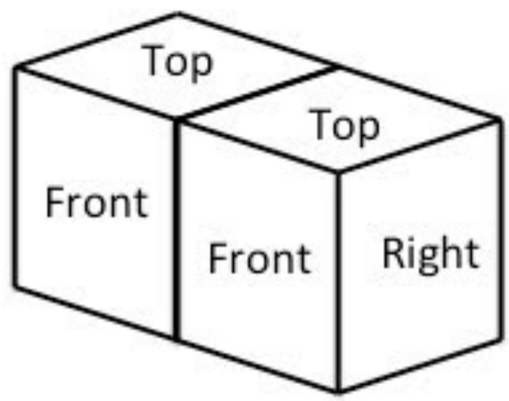

Figure 1. 2-cube structure

> **TEACHER NOTES**
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> **Strategy for students who lose count:** Have them go view by view: ‘How many faces from Top? Front? Right? Left? Bottom? Back?’ Add all six. This directly connects to the 3-view drawing skills from Module 3. For students who learned nets in Module 2, offer an alternative strategy: ‘Imagine unfolding the structure into a net. How many squares are in the net? That number is the surface area.’ Both methods should produce the same answer — if they do not, the student has missed a face or counted one twice.
>
> **Common error:** Students often forget the bottom and back faces. Remind them: 'Go all the way around — six sides total.'

ACTIVITY 2

Station Rotations: Calculate Volume and Surface Area

Essential Question: How do volume and surface area change when a structure chages shape?

TIME
~60 minutes

Set up 4 to 6 cube structures around the room as stations. Students rotate through each station and calculate the volume and surface area of each structure using the Student Recording Sheet.

TEACHER NOTES

Station setup: Number each station. Include at least 1 simple structure (2 cubes in a row), 2 medium structures (4–6 cubes with a level change), and 1 complex structure (7+ cubes with multiple changes of plane). Allow 8–12 minutes per station.

ACTIVITY 3

Using 3-View Drawings to Calculate

Essential Question: How can a 2D drawing help us calculate volume and surface area?

TIME
~45 min

Students use their 3-view drawings as a calculation tool — not just as a way to communicate the shape.

THE CONNECTION: DRAWING AND CALCULATING

A good 3-view drawing shows every change of plane in a structure — which means it shows every exposed face. Counting faces view by view directly gives total surface area:

Top + Bottom + Front + Back + Right + Left = Total Surface Area

Part 1 — Draw First, Then Calculate (25 minutes)

Set up a new cube structure at the front of the room (5 to 8 cubes). Students:

1. Draw the 3-view (Top, Front, Right) using engineering notation.
2. Use the drawings to count exposed faces and calculate the surface area.
3. Count the unit cubes and calculate the volume.
4. Check their work by physically examining the structure.

Part 2 — Explore: What Happens When Shape Changes? (15 minutes)

Give students 4 cubes. Have them build different structures (straight line vs. L-shape vs. stack) and compare.

DISCUSSION QUESTIONS

- If you rearrange the same 4 cubes into a different shape, does the volume change?
- Does the surface area change when you rearrange? Which arrangement has the most? The least?
- Why might an engineer care about how much surface area a design has?

TEACHER NOTES

Key insight to draw out: Volume does not change when you rearrange the same number of cubes. But surface area does — spreading cubes out exposes more faces; stacking them hides more faces. This is a powerful design insight.

ACTIVITY 4

Connecting to Design Decisions

Essential Question: How do volume and surface area affect engineering design?

TIME
~30min

Class Discussion – Design Constraints (15 minutes)

DESIGN SCENARIO

Imagine you are designing a small storage container using 8 unit cubes of material.

1. If you care about having the most storage space inside, which arrangement would you choose? (All arrangements have the same volume: 8 in^3.)
2. If you need to coat the outside with a protective material, which arrangement uses the least? (Hint: the one with the least surface area.)
3. Are there other design factors that might matter — shape, stability, ease of access?

Journal Reflection (15 minutes)

✏️JOURNAL PROMPT

Choose ONE structure from the station activity and answer:

1. What is the volume of your structure? Show how you counted.
2. What is the surface area? Show how you counted.
3. Sketch the structure (or draw the 3-view). Label the measurements.
4. Give one real-world example where knowing volume would matter. Give one where knowing surface area would matter.
5. How can engineering drawing, volume, and surface area help you when you design something?

Engineering Drawing Modules Wrap-Up

What We Learned Across All Three Modules

Module 1: We explored observation sketching, built vocabulary for describing 3D objects (face, edge, vertex), and discovered through partner sketching that informal drawing cannot reliably communicate a complete 3D design.

Module 2: We built and drew cube nets — discovering that a 2D representation needs to show all exposed faces to describe a 3D object completely, and made our first connection to surface area.

Module 3: We learned 3-view drawing — the engineering standard for giving complete, accurate information about a 3D shape. We used it to communicate designs to a partner.

Module 4: We used our drawings and physical structures to calculate volume and surface area, and connected those calculations to real engineering design decisions.

Companion Handouts

Handout 1 — Student Recording Sheet

Station	Structure Description / Sketch	Volume (in^3)	Surface Area (in^2)
1			
2			
3			
4			
5			
6			

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