Lesson 05: Fermi Estimation - How Many? (Low-Inquiry Version)

Lesson Title: Fermi Estimation: Following the Formula
Intended Grade Level(s): Grades 6-12 (adaptable)

I. Planning

Lesson Focus / Goals

The lesson aims to provide the following for students:

- Practice making large-scale estimates using provided formulas
- Learn to break down complex problems into smaller sub-problems
- Understand how to use given assumptions to calculate estimates

Learning Objectives

By the end of the lesson, students will be able to:

- Follow a multi-step estimation formula provided by the teacher
- Substitute given values into the formula correctly
- Calculate estimates using the provided assumptions
- Verify their answer matches the expected range

Standards Alignment

Standards for Mathematical Practice (Common Core):

- **MP1** – Make sense of problems and persevere in solving them.
- **MP2** – Reason abstractly and quantitatively.

NGSS Science and Engineering Practices:

- **Using Mathematics and Computational Thinking** – Students use mathematical formulas to model real-world phenomena.
- **Developing and Using Models** – Students create mathematical models to represent complex systems.

Materials Needed

The following materials are used in the lesson:

- **Fermi problem worksheet** with the problem and step-by-step formula provided
- **Assumption cards** with all values students need (population, average values, etc.)
- **Calculators** for computation

- **Teacher worked example** on chart paper showing the complete solution process
- **Answer key** with acceptable range of answers

II. Implementation

Lesson Flow

Before: (Launch – 8 min)

1. Present the **Fermi question**: "How many piano tuners are in Chicago?"
2. Acknowledge: "This seems impossible! But we can estimate it using a formula."
3. Explain: "Fermi problems are named after physicist Enrico Fermi, who was famous for making quick estimates."
4. Show **teacher worked example** for a similar problem: "How many gas stations are in Ohio?"
   - Step 1: Population of Ohio = 11,000,000 (given)
   - Step 2: Average cars per household = 2 (given)
   - Step 3: Average household size = 2.5 people (given)
   - Step 4: Number of households = 11,000,000 ÷ 2.5 = 4,400,000
   - Step 5: Number of cars = 4,400,000 × 2 = 8,800,000
   - Step 6: Cars per gas station = 2,000 (given)
   - Step 7: Number of gas stations = 8,800,000 ÷ 2,000 = 4,400
5. Emphasize: "The key is following the formula step-by-step using the given values."

During: (Explore – 12 min)

- Distribute **Fermi problem worksheets**: "How many piano tuners are in Chicago?"
- Provide **assumption cards** with all needed values:
  - Population of Chicago = 2,700,000
  - Percentage of households with pianos = 3%
  - Average household size = 2.5 people
  - Pianos tuned per year = 1 time
  - Pianos one tuner can service per year = 200
- Show the **formula on board:**

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Step 1: Calculate number of households (Population ÷ Household size)
Step 2: Calculate households with pianos (Households × Piano percentage)
Step 3: Calculate total pianos (same as households with pianos - assume 1 piano per hou
Step 4: Calculate pianos tuned per year (Pianos × Tunings per year)
Step 5: Calculate piano tuners needed (Pianos tuned ÷ Pianos serviced by one tuner)
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- Students work through the formula, filling in each step on worksheet
- Teacher circulates to ensure students:
  - Are using the provided assumption values
  - Are following the steps in order
  - Are showing their calculations
- After 10 minutes, teacher shows the solution on board, step-by-step
- Students verify their answers match

After: (Discuss – 5 min)

- Reveal: "The actual number of piano tuners in Chicago is about 290. Our estimate of 400 is pretty close!"
- Ask: "Why is estimation useful?"
- Teacher explains: "Scientists and engineers use Fermi estimation when exact data isn't available."
- Emphasize: "The formula gives us a systematic way to break down big questions."
- Note: "As long as your answer is within one order of magnitude (10× to 0.1×), it's a good estimate."

III. Assessment

Formative: During the lesson, monitor if students:

- Are following the formula steps in the correct order
- Are using the provided assumption values (not making up their own)
- Are showing their calculations for each step
- Arrive at an answer within the acceptable range

Exit Ticket: Students complete one more Fermi problem following a provided formula: "How many text messages are sent in the US per day?" (formula and assumptions provided)

Peer/Self-Assessment: Students compare their step-by-step calculations with a partner to verify they used the same approach.

Student Worksheet

Name: _____ **Date:** _____

Fermi Estimation: How Many Piano Tuners in Chicago?

The Problem:
How many piano tuners work in Chicago?

The Approach:
We'll use a formula to estimate this. Follow each step carefully and show your work.

Given Assumptions (Use these values!)

- Population of Chicago = **2,700,000 people**
- Average household size = **2.5 people**
- Percentage of households with pianos = **3%**
- Times a piano is tuned per year = **1 time**
- Pianos one tuner can service per year = **200 pianos**

Formula Steps

Step 1: Calculate the number of households in Chicago
Number of households = Population ÷ Household size
= _____ ÷ _____ = _____

Step 2: Calculate the number of households with pianos
Households with pianos = Households × Piano percentage
= _____ × _____ = _____

Step 3: Calculate the total number of pianos
(Assume 1 piano per household)
Total pianos = _____

Step 4: Calculate the number of piano tunings needed per year
Tunings per year = Total pianos × Tunings per piano
= _____ × _____ = _____

Step 5: Calculate the number of piano tuners needed
Piano tuners = Tunings per year ÷ Pianos serviced by one tuner
= _____ ÷ _____ = _____

Final Answer

Our estimate: About _____ piano tuners in Chicago

Exit Ticket

New Problem: How many text messages are sent in the US per day?

Given Assumptions: - US population = 330,000,000 - Percentage who text = 80% - Average texts per person per day = 50

Formula: 1. Calculate texters: Population × Texting percentage = _____ 2. Calculate total texts: Texters × Texts per person = _____

Answer: About _____ text messages per day