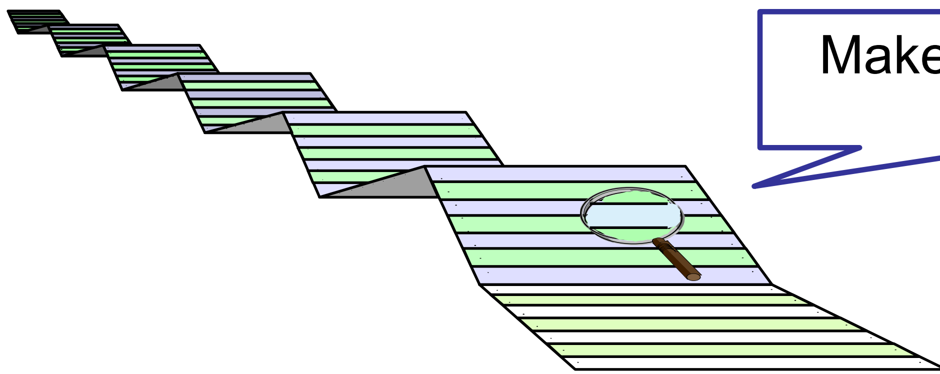
The First Four Steps

1. Collect and analyze information and data.
2. Talk with people familiar with the problem.
3. If at all possible, view the problem firsthand.
4. Confirm all findings.

The First Four Steps – Step 1

Step 1: *<u>Collect and Analyze Information and Data</u>*

Five to six weeks in the laboratory can save you an hour in the library.



Make the data talk!!!

The First Four Steps – Step 1

Collecting Information

- Google/Web Search
- Library Search
- Recall a Related Problem in a Class or Textbook
- Company or Other Reports (Old and New)
- Surveys
- Interviews

The First Four Steps – Step 1

Make the Data Talk

Set A		Set B		Set C		Set D	
X	Y	X	Y	X	Y	X	Y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
12.0	10.84	12.0	9.113	12.0	8.15	8.0	5.56
7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.89

Each of these four data sets A, B, C, and D *all* have the following properties:

$N = 11$ Mean of X's = 9.0 Equation of regression line: $Y = 3 + 0.5\,X$

$t = 4.24$ Mean of Y's = 7.5 Standard error of estimate of slope = 0.118

$r^2 = 0.67$ Correlation coefficient = 0.82 Sum of squares $(X - \bar{X})^2 = 110.0$

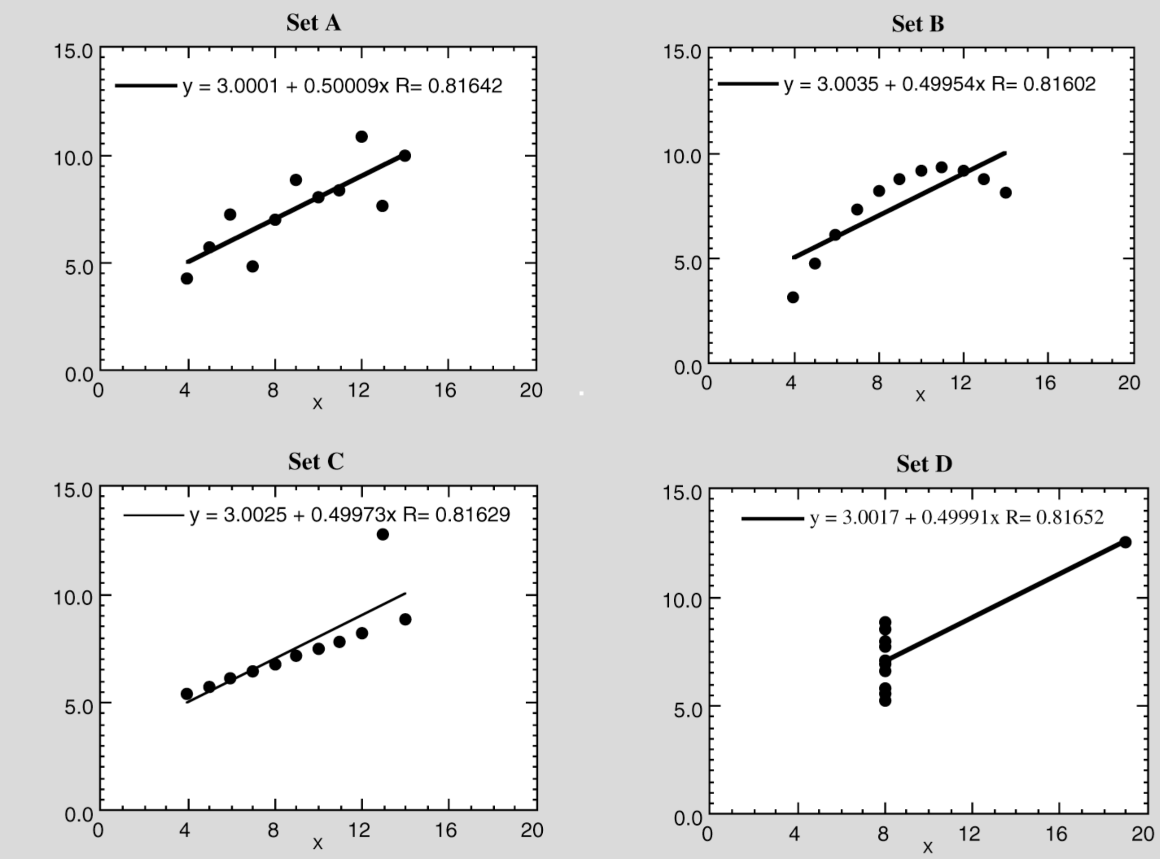
Regression sum of squares = 27.50 Residual sum of squares of Y = 13.75

Anscombe's Quartet Table

Statistically everything looks the same!!

The First Four Steps – Step 1

Make the Data Talk



Plots of Data Sets with Same Statistical Properties

The First Four Steps – Step 2

Step 2: *<u>Talk with people familiar with the Problem</u>*

- Find out who knows about the problem.

- Ask penetrating questions by using critical thinking and Socratic questioning. (Ch.3)

Ask Insightful Questions

The First Four Steps – Step 2

Step 2: *<u>Talk with people familiar with the Problem</u>*

Find out who knows about the problem.

Ask penetrating questions by:

- Looking past the obvious
- Challenging the basic premise of proposed reason
- Asking for clarification when you do not understand something.

Use the 6 types of Socratic Questions

Ask Insightful Questions

The First Four Steps – Step 2

Go Talk to George

Let's consider a situation in which, immediately upon replacement, a brand new flow meter begins to leak. List, in order, four people you would talk to.

The First Four Steps – Step 2

Let's consider a situation in which, immediately upon replacement, a brand new flowmeter begins to leak. List, in order, four people you would talk to.

1. **The person who installed the meter.**
2. **The technician who monitors the flowmeter.**
3. **The manufacturer's representative who sold you the flowmeter.**
4. **George.**

The First Four Steps – Step 2

Who's George?

- Every organization has a George. George is that individual who has years of experience to draw upon and also has street smarts.

- George is an excellent problem solver who always seems to approach the problem from a different viewpoint– one that hasn't been thought of by anyone else.

- Verbalizing the problem to individuals such as George can often provide a unique perspective on the situation.

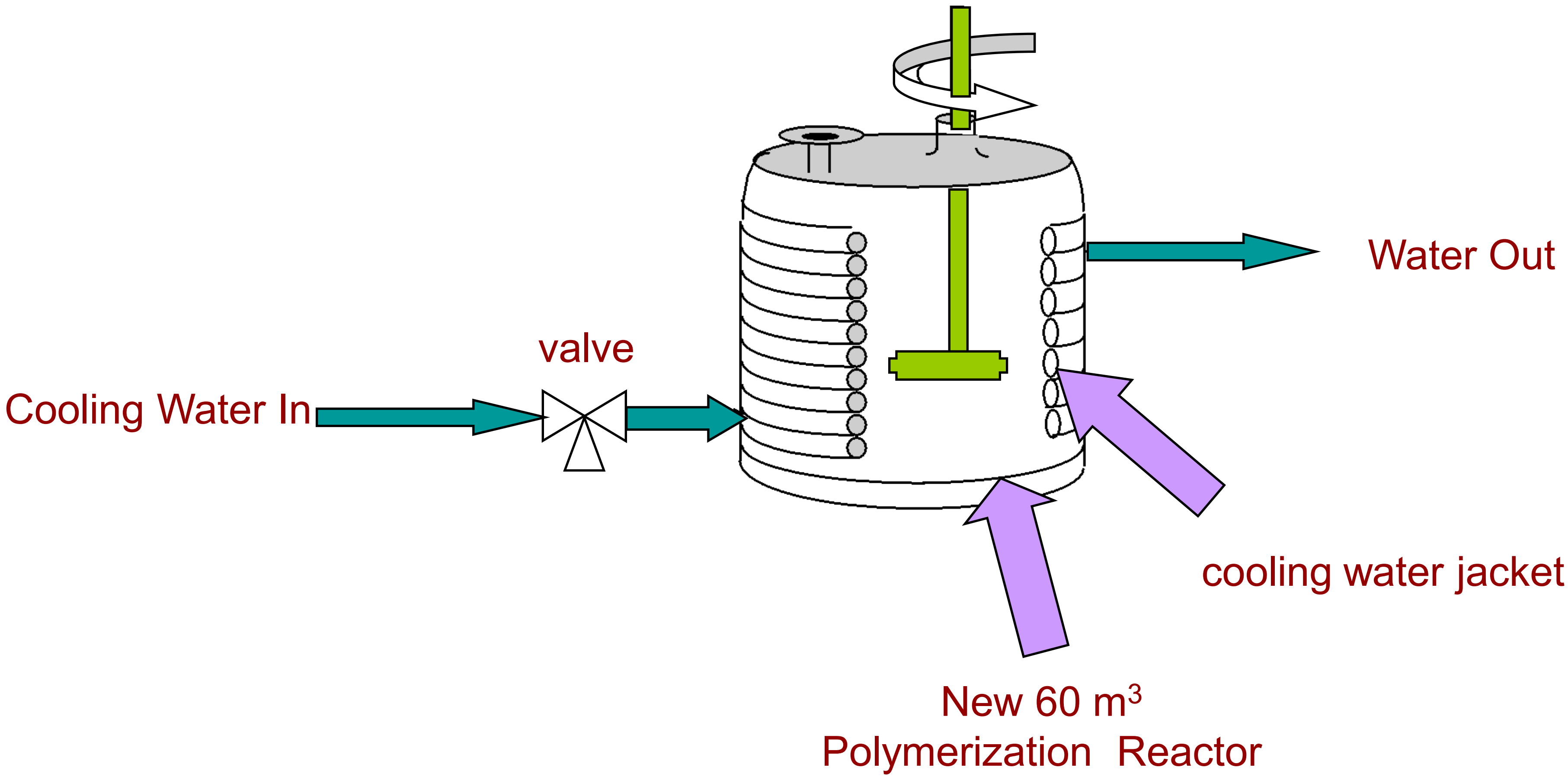
The First Four Steps – Step 3

Step 3: *View the Problem First Hand*

In the mid 1970s a company in the United Kingdom completed a plant to produce a plastic product (PVC). The main piece of equipment was a large reactor with a cooling jacket through which water passed to keep the reactor cool. When the plant was started up, the plastic was dark, nonuniform, and way off design specifications.

The First Four Steps – Step 3

Off-spec Polymer



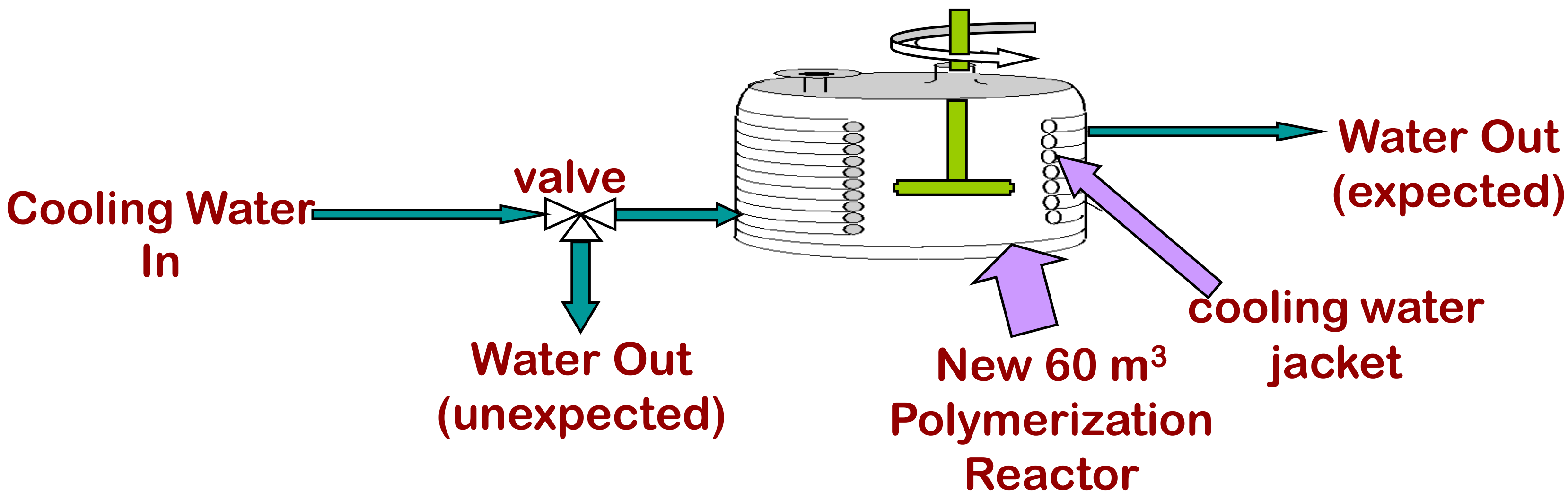
The First Four Steps – Step 3

What did they do?

- Reworked and refined their model and calculations
- Analyzed the procedure from every point of view on paper, and
- Had the raw material fed to the reactor analyzed.
- Unfortunately, nobody examined the reactor firsthand
- Finally after many days, one of the engineers decided to look into the reactor.

The First Four Steps – Step 3

However, they came up with the same results.



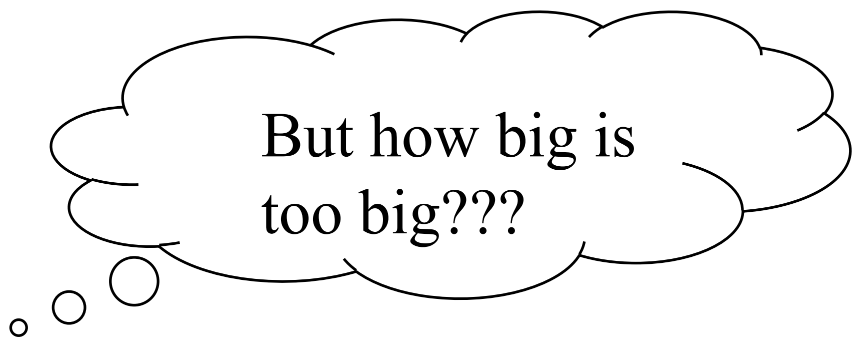
He found that a valve had been carelessly switched to the wrong position, thereby diverting cooling water away from the reactor so that virtually no cooling took place.

As a result the reactor overheated, producing a poor quality product. Once the valves were adjusted properly, the high quality plastic was produced.

The First Four Steps – Step 4

Step 4: *<u>Confirm all Findings</u>*

Remember to double check all findings



Attending Class

Original Problem Statement: Most students in Professor Hammersmith's class do not attend class regularly.

Trigger 1: Vary the stress pattern – try placing emphasis on different words and phrases.

- **Most** students in Prof. Hammersmith's class do not attend lectures regularly. What distinguishes the few students who come regularly from those who don't? What motivates these students to come to class?
- Most **students** in Prof. Hammersmith's class do not attend lectures regularly. Does the lack of attendance have anything to do with the lifestyle of a student? Do they sleep so late at night that they are unable to wake up in time for class?

Attending Class

Original Problem Statement: Most students in Professor Hammersmith's class do not attend class regularly.

Trigger 1: Vary the stress pattern – try placing emphasis on different words and phrases.

- Most students in **Prof. Hammersmith'**s class do not attend lectures regularly. Is the problem specific only to Prof. Hammersmith or do other professors also face this problem?
- Most students in Prof. Hammersmith's class do not attend **lectures** regularly. Are the lectures boring? Are the lectures so early in the morning that students are unable to wake up?

Attending Class

Original Problem Statement: Most students in Professor Hammersmith's class do not attend class regularly.

Trigger 2: Choose a term that has an explicit definition and substitute the explicit definition in each place that the term appears.

- Most students in Prof. Hammersmith's class do not attend '**an oral presentation intended to present information or teach people a particular subject**' regularly. Do students feel that they are not learning much out of the lectures? Do they feel that they can learn the subject on their own and do not find the need to attend lectures?

Attending Class

Original Problem Statement: Most students in Professor Hammersmith's class do not attend class regularly.

Trigger 3: Make an opposite statement, changing positives to negatives and vice versa.

- Most students in Prof. Hammersmith's class **attend** lectures regularly. In general, what are the things that make students want to attend lectures? One reason may be that the lectures are so much fun that students don't want to miss out on them. Another reason is that the lecture contains material that students will not be able to learn on their own in case they miss the lecture. A third reason is that the instructor conducts surprise quizzes during lecture hours and it will affect students' grades if they miss them.

Attending Class

Original Problem Statement: Most students in Professor Hammersmith's class do not attend class regularly.

Trigger 4: Change "every" to "some", "always" to "sometimes", "sometimes" to "never" and vice versa.

- **Some** students in Prof. Hammersmith's class do not attend lectures regularly. Out of the many students who do not attend lectures (in the original statement), is it possible that some of them face problems such as chronic illness, alcoholism or drug addiction? Is it possible to help these students out?

Attending Class

Original Problem Statement: Most students in Professor Hammersmith's class do not attend class regularly.

Trigger 5: Replace "persuasive words" in the problem statement such as "obviously", "clearly", and "certainly" with the argument it is supposed to be replacing.

- Our problem statement has no such persuasive words and hence this trigger cannot be applied.

Attending Class

Original Problem Statement: Most students in Professor Hammersmith's class do not attend class regularly.

Trigger 6: Express words in the form of an equation or picture, and vice versa.

$$\text{Attendance} = \frac{k * A * B * C}{D}$$

A: knowledge gained (which cannot be obtained outside)

B: how interesting students find the lecture

C: penalty for missing a lecture

D: How early in the morning is the lecture held

k: Other factors such as addiction, illness etc.

Fermi Problems

- Enrico Fermi:
  - 1938 Nobel Laureate for elementary particle physics
  - 1942 First sustained nuclear reaction
- Famous for his back of the envelope calculations.
- A Fermi problem has a characteristic profile:

  Upon first hearing it, one doesn’t have even the remotest notion what the answer might be.

Fermi Problems

One feels certain that too little information exists to find a solution

Yet, when the problem is broken down into sub problems, each one answerable

Without the help of experts or reference books, an estimate can be made, either mentally or on the back of an envelope, that comes remarkably close to the exact solution

Fermi Problems

- What do you know is relevant?
- What assumptions can you make?
- How plausible are your assumptions?
- Is your chain of reasoning accurate?
- Can you do the problem another way and see if the result is the same?
- In your answer, do you spell out your assumptions, reasoning, solution, and checking procedure clearly?

Fermi Problems

Q: How many piano tuners in the city of Chicago?

A.	Population of Chicago	4,000,000
B.	Size of Households	4
C.	Number of Households	1,000,000
D.	Fraction of Households that own a piano	1/5
E.	Number of Pianos	200,000
F.	Number of Tunes/year per Piano	1
G.	Number of Tunes Needed Per Year	200,000
H.	Tunes per day	2
I.	Tunes per year per tuner	

$$\frac{250\ days}{yr} \times \frac{2}{day} =$$ 500/yr/tuner

$$\frac{200{,}000\ tunes}{yr} \times \frac{1}{500\ tunes/yr/tuner} =$$ 400 Tuners

Fermi Problems

<u>Refinement</u>

Add Churches

$$4{,}000{,}000\ people \times \frac{1\ church}{500\ people} \times \frac{1\ panio}{church} = 8{,}000\ pianos$$

Add Schools

$$4{,}000{,}000\ people \times \frac{1}{2} school\ age \times \frac{1\ school}{400\ people} = 5{,}000\ pianos$$

$$200{,}000 + 8{,}000 + 5{,}000 = 213{,}000\ pianos$$

$$400\ Tuners \times \frac{213{,}000\ pianos}{200{,}000\ pianos} = 426\ Tuners$$