# Introduction to Quantitative Research Methods

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# Quantitative Research Methods

- *Quantitative* methods are those that deal with measurable data.

It is data that is codified, meaning:

- It has an *amount* that can be directly measured.
- The amount is with respect to some known *units* of measurement.
- The units are known so *comparisons* of measurements are possible.
- The comparisons are *numerically* based.
- *Results* are based on such data comparisons.

- Quantitative methods are often used in technical fields, such as in science and engineering.

- Using quantitative methods properly are key to your success in these areas!

# Quantitative Methods and Goals

- The ultimate goal is an understanding of how to collect, analyze and communicate data in an experiment. Specifically:
- The ROLE of data in a scientific study. What it really is for. It is far more important than you may think.
- PLANNING to get the data you need. What kind of data, and how much is enough.
- How to MEASURE data. How to obtain the data you need.
- How to express the SIGNIFICANCE of your data. Showing what your data means.
- You should be able to exercise these skills as an independent scientist, employee, entrepreneur or consultant.

# Quantitative and Qualitative methods

- *Qualitative* methods deal with non-numeric data.
- Broad things like verbal information or human experience.
- It is not that one is better than the other!  It depends on the study you are doing.
- You should choose the right study method that best fits the problem you are trying to solve.
- References on scientific method often compare Quantitative and Qualitative methods, but the comparison can get abstract.

# Differences

## Quantitative:

- Numbers
- Researcher's opinions
- Distance
- Theory testing
- Numerical based analysis
- Structured

## Qualitative:

- Words
- Participant's opinions
- Closeness
- Theory generation
- Process based analysis
- Unstructured

# Differences

**Quantitative:**

- **Explanation**
- **Prediction**
- **“Hard” data (measurements)**
- **Objective intent**
- **Closed (laboratory) environment**

**Qualitative:**

- **Understanding**
- **Interpretation**
- **“Soft” data (diverse and rich)**
- **Subjective tolerance**
- **Open (natural) environment**

# The ROLE of data, or what data is for (a possible quantitative example from real life)

Suppose you are working for a company that designs a RFID based parking payment system. Here is how it works:

- A customer parks a car in a pay-for-time parking space.
- When the customer goes to drive away, they pay for their parking time at a machine.
- The machine gives them a RFID tag that is used to activate a gate that lets them leave the parking area.

**<u>YOU</u>** must design the RFID system such that:

1. The RFID tag MUST be able to activate the gate when held <u>4cm or less</u> from the gate reader.
2. The RFID tag MUST be read within <u>0.5 seconds</u> when held 4cm or less from the gate reader.

Note the reliance on numeric parameters.

# Product Rollout!
# and the boss asks “Does your RFID design work??”

Which of these answers would you be able to give to the boss?

1. “I don’t know.”
2. “It works *most of the time*.”
3. “If you hold the *tag steady and close enough*, it should be OK.”
4. “When the tag is held between 0 cm and 4 cm of the reader’s antenna, the gate will open within 0.5 seconds in 99% of attempts.

# Let the Data Speak!

The whole point of data is to *quantitatively* show the value of something.

- *Show* how well something works with minimal ambiguity.
- Accurately *predict* how well something can or will work.
- Allow people to *verify* your work by re-doing it.
- *Resolve* selection criteria. Which solution is better based on what?

Other, no less valuable uses:

- Know the preliminary value of a new idea quickly and clearly.
- Establish your credibility. That you know what you are talking about.
- To teach. To pass on knowledge of benefit to others.
- To communicate in a way that others can understand.
- Remove the non-useful elements from technical decisions.

# Two approaches to experiment design: Deduction and Induction

Deduction:

- In this type of study, you start with a hypothesis based on known facts, physical laws or theory.
- You then seek to confirm or reject your hypothesis based on the experiments you perform.
- This is called an approach based on *Deduction*.

1: Theory -> 2: Hypothesis -> 3: Observation -> 4: Accept or Reject

# Two approaches to experiment design : Deduction and Induction

Induction:

- In this type of study, you have no existing theory, laws or facts you can go on. You can't form a hypothesis based on those.
- So instead, you perform experiments and observe the results.
- The observed results hopefully suggest a repeatable pattern or repeatable outcomes.
- Based on the pattern or outcomes, a "tentative hypothesis" is formed.
- The tentative hypothesis forms the basis of a new theory.

1: Observation -> 2: Outcomes -> 3: Tentative Hypothesis -> 4: Theory

# Deduction and Induction
# Which is better?

- It depends on the problem you are trying to solve. Your *problem statement*.
- If your problem statement is based in known theory, facts or physical laws, then you can take a deductive approach.
- If the problem statement is not based on such theory or fact, ie because they don’t exist, then you take an inductive approach.
- Neither approach is perfect. Although a deductive approach allows for a result to be “proved”, it is only proved in the context of the rules and laws. There is no room to deviate.
- The inductive approach does give room to deviate, but no actual proof of the outcome (the resulting theory) is immediately possible. The tentative hypothesis stays tentative until the theory is proven.

# Ingredients of a quantitative study

- No matter if the study is deductive or inductive, we can generalize the steps that make up a good repeatable study.

- Problem Statement
- Literature Study
- Experiment design
- Data collection
- Data Analysis
- Study Conclusions

# 1. Problem Statement

- What is the problem or question that you are trying to solve?
- You need to make this very clear at the start of your study.
- It serves to define the scope and purpose of your study.
- Without it, it is very hard to form a hypothesis in a deductive approach or experiments in an inductive approach.
- Without it your study has no bounds. “If you don’t know where you are going, any road will get you there.”

# 2. Literature Study

- This is a survey of the current *State of the Art.* What do people already know about the problem you are trying to solve.

- Knowledge is power. The literature study gives you that power. Any published knowledge base. Journals, books, conferences, etc.

- You know what has already been done and the outcomes.
- You know the challenges, successes and failures that others have identified and experienced.
- You can use this to decide how you will proceed by exploiting what other have done, and learning from their experience.
- You will know what your expected contributions are.
- You may even be able to solve the problem statement just from the literature study. No experiment needed.

# 3: Experiment Design

- This is a full description of how the experiments that you will do will be designed and run.
- It provides a mechanism to make experiments *repeatable*. In other words for an experiment to prove something it needs to always give the same results under the same conditions.
- Also demonstrates *how* you will get quantitative data that has meaning.

- Full description of all materials and methods.
- Full description of all equipment and processes.
- Full description of material sources and suppliers.
- Full description of any human or animal subjects used.
- Full description of the environment under which the experiments are run and data is collected.

- This all allows for independent verification of your results.

# 4: Data Collection

- This describes the nature of the raw data that is collected.
- It needs to actually be a measure of quantities that addresses your problem statement and hypothesis. In other words, you need to measure the right thing.
- It takes into account *accuracy*, *precision* and *resolution*.
- It addresses any unavoidable *bias* that the data may have.
- The *amount of data* that is collected is important.

# 5: Data Analysis

- In this step you summarize your raw data in a way that:
- Any competent researcher in your field can understand your data without having to look at every measured value.
- Allows your data to show trends, variance, probabilities, errors or any other quantities that “allow the data to speak” for you.
- Allows the *significance* of the data to be understood. In other words, does the data mean anything, and if it does what does it mean?

# 6: Study Conclusions

- It is here that you connect your data with your hypothesis.

- In a deductive study, you use the data to confirm or reject your hypothesis.

- In a inductive study, you use the data to form a "tentative hypothesis" that can lead to a theory.

- You also can explicitly state what *impact* your study ultimately has. In other words, what is the bigger picture that the results of your study suggests? For example:

- "The technology is possible and will be disruptive in the market."
- "The environment of future cities will benefit."
- "The basis for an entire new industry can be created."

# Next Steps

- There are lots of methods, techniques and processes that can help you design and run good qualitative studies that give concrete results.
- Letting the data speak is a powerful tool for any scientist and engineer.  Always let it speak for you if you can!
- In a future lecture we will go into the details of many of these steps and focus on what is important.
- In the lab sections we will try many of these methods, techniques and processes.