

Inquiry Webinar 6

Experimental Inquiry

The goal of **INQUIRY** is to expand our **KNOWLEDGE** by looking for an **ANSWER** to questions whose answers we do not know.

In **EXPERIMENTAL INQUIRY**, we *conduct experiments* to find answers to our questions.

Before we actually conduct an experiment, it is important to:

- A. think about the **QUESTION** - What is it that we wish to find out? Formulate it as clearly and precisely as possible, and
- B. plan the **DESIGN OF THE EXPERIMENT**. What so we need to do such that the outcome of the experiment will help us answer our question?

Once we have the experiment design, we need to:

- C. conduct the experiment, and observe the **OUTCOME**; and
- D. arrive at an **ANSWER** that we can accept as reliable **KNOWLEDGE**.

In a simple experiment like this one, the answer to our question is our **CONCLUSION**.

Our goal in the webinar was to use fragrance and non-fragrance of jasmine flowers as an example to give you a broad understanding of the ideas mentioned above. It was not to provide a body of knowledge about the fragrance of jasmine flowers, or help you develop the abilities for experimental inquiry.

Most literature on experimental science presents experimental inquiry as a process of **HYPOTHESIS TESTING**. The webinar adopts a more comprehensive view by taking the vantage point of scientific theoretical inquiry, and presents experiments as involving **PREDICTION TESTING**.

A norm of controlled experiments is to change one factor (variable) at a time, keeping all other factors constant. In our prediction testing mode, we introduced a mode of experimenting where we controlled two factors in a sequence of experiments. This allows for an appreciation of testing factors in isolation as well as the **interaction** of factors in combination.

The prediction testing mode is crucial for experiment design guided by a theory. Hypotheses of the form "If X and Y, then Z," and "If X or Y, then Z," stated in Part 4, constitute the beginnings of theory driven experimentation. Question 10 at the end, pointing attention to experiment design in theoretical science, is for you to explore this domain further.

Part 1: The first round

Aryan and Zoya each buy a baby jasmine plant from a nursery. The plants come from the same mother plant. In a few weeks, both plants bloom.

Z's jasmine flowers are fragrant, A's are not.

Q1: What could have made the difference?

A GUESS:

The difference has to do with the quantity of water each plant gets.

Z: Aryan, did you water your plant?

A: Yes. You?

Z: Yes, of course. How often? I watered it every day.

A: Oh! I did it only on alternate days.

Z: And how much water each time?

A: About half a cupful.

Z: Why so little? I gave it a full cup every day.

A: My last jasmine plant died because I overwatered it.

Z: May be your flowers were not fragrant because the plant didn't get enough water

HYPOTHESIS 1: If a jasmine plant doesn't get enough water, then its flowers will not be fragrant.

Q2: How do we test this hypothesis?

STEPS: We get more plants of the same variety from the same nursery.

We separate the plants randomly into two sets. We place them in exactly the same kind of environment: the only difference between them is in the amount of water we give them.

To **Set 1**, we give what we judge to be **enough water**.

To **Set 2**, we give less — what we judge as **not enough water**.

Here are the questions we need to ask in order to figure out whether or not Hypothesis 1 is right.

Q3: What are the **possible outcomes** of our test?

Q4: What **conclusions** do we arrive at from each outcome?

Part 2: The investigation

Set 1, we give what we judge to be **enough water**.

Set 2, we give less — what we judge as **not enough water**.

OUTCOME A: What can we say if:

In both sets of plants: Flowers are fragrant.

CONCLUSION: Hypothesis 1 is wrong.

Even without enough water, the flowers in Set 2 are fragrant. The difference in fragrance between Aryan's and Zoya's flowers is not because of the amount of water the plants get.

OUTCOME B:

In both sets of plants: Flowers are not fragrant.

CONCLUSION: **The outcome doesn't help us figure out why**

there is a difference in fragrance between Aryan's and Zoya's flowers. It doesn't explain why, even with enough water, the flowers in Set 1 are not fragrant.

OUTCOME C:

In Set 1: Flowers are not fragrant.

In Set 2: Flowers are fragrant.

CONCLUSION: Hypothesis 1 is wrong.

The outcome goes against it. The amount of water *may not be* relevant.

OUTCOME D:

In Set 1: Flowers are fragrant.

In Set 2: Flowers are not fragrant.

CONCLUSION: Hypothesis 1 is right. It makes the correct PREDICTION.

Part 3: An Alternative hypothesis

Q5: If the outcome of our test is A, B, or C, how do we proceed?

Given outcomes A, B, or C, we must look for some other reason for why A's flowers are not fragrant.

A GUESS:

The difference has to do with the amount of sunlight each plant gets.

Z: My plant is on the balcony, where it gets sunlight all day.

A: Mine is on the kitchen window. It gets sunlight only for a while, in the morning.

Z: May be that's not enough.

HYPOTHESIS 2: If a jasmine plant doesn't get enough sunlight, then its flowers will not be fragrant.

Q6: How do we test hypothesis 2?

STEPS: We get more plants of the same variety from the same nursery.

We separate the plants randomly into two sets. Keeping everything else the same, including the amount of water, we place:

Set 3 in a location where the plants get **sunlight all day**; and

Set 4 in a location where the plants are **mostly in the shade**.

Q7: What are the **possible outcomes** of our test 2?

Q8: What **conclusions** do we arrive at from each outcome?

OUTCOME E:

In both sets of plants: Flowers are fragrant.

CONCLUSION: Hypothesis 2 is wrong.

Even without enough sunlight, the flowers in Set 4 are fragrant. Hence, the difference between A's and Z's flowers is not because of the amount of sunlight that the plants get.

OUTCOME F:

In both sets of plants: Flowers are not fragrant.

CONCLUSION: The outcome doesn't help us figure out why

there is a difference in fragrance between A's and Z's flowers. It doesn't explain why, even with enough sunlight, the flowers in Set 3 are not fragrant.

OUTCOME G:

In Set 3 (enough sunlight): Flowers are not fragrant.

In Set 4 (not enough sunlight): Flowers are fragrant.

CONCLUSION: Hypothesis 2 is wrong.

The outcome goes against it. The amount of sunlight *may not be* relevant.

OUTCOME H:

In Set 3 (enough sunlight): flowers are fragrant.

In Set 4 (not enough sunlight): flowers are not fragrant.

CONCLUSION: Hypothesis 2 is right. It makes the correct **PREDICTION.**

Q9: What do we do next?

Part 4: Exploring further

ThinQabout:

Suppose it turns out that for the flowers to be fragrant, the plants need **BOTH** enough water **AND** enough sunlight. If any one of them is missing, the flowers will not be fragrant.

Or it may turn out that for the flowers to be fragrant, the plants need **EITHER** enough sunlight **OR** enough water. If so, the plants will have fragrant flowers even if there isn't enough sunlight, as long as there is enough water. And the flowers will be fragrant even if the plants don't get enough water, as long as there is enough sunlight. But if both are insufficient, then the flowers will not be fragrant.

The hypotheses expressing these ideas are given below:

HYPOTHESIS 3:	If a jasmine plant doesn't get enough water AND enough sunlight, then its flowers will not be fragrant.
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HYPOTHESIS 4:	If a jasmine plant doesn't get EITHER enough water OR enough sunlight, then its flowers will not be fragrant.
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For you to pursue further if you are interested:

Q10: How do we design experiments to test hypotheses 3 & 4?