ABSTRACT

This article explains four kinds of inquiry exercises, different in purpose, for teaching advanced-level high school and college students the hypothetico-deductive (H-D) method. The first uses a picture of a river system to convey the H-D method’s logic. The second has teams of students use the H-D method: their teacher poses a hypothesis drawn from a research article the students have not seen and asks them to design an H-D test of it. Later they read the article and compare their designs with its. The third exercise extends this; when economically practical, the class may experimentally test the best of its designs. Finally, an Internet/library exercise lets students inquire into the history of the H-D method.

Key Words: Hypothetico-deductive method; inquiry-based learning; case study method.

One aim of biology courses is to give students an understanding of the hypothetico-deductive (H-D) method, widely used for testing research hypotheses. Some students will become scientists, having occasion to do research with the H-D method and to evaluate research based on it; others will become science teachers, charged with helping students learn it. And all will become adults who ought to understand it, since much of the scientific knowledge that affects them and society is discovered with it.

How well is this aim achieved? Consider that Niaz (2004), testing 83 university science graduates, found that approximately 60% could not elaborate the difference between a hypothesis and a prediction, key elements of the H-D method. Cortéz and Niaz (1999), testing 110 eleventh-grade science students, found that only 37.3% adequately understood the H-D method’s logic, and concluded: “school curricula should include development of students’ hypothetico-deductive reasoning abilities.”

Teaching the H-D Method’s Logic Using a Picture

To begin, the teacher gives the students a picture of the river system shown in Figure 1, asking them to imagine:

You are standing at place A on the main river, 10 miles downstream from a dam. Upstream, below the dam, out of sight of place A, another river – call it the “shunt river” – flows into the main river. Suddenly a distant rumble suggests to you this hypothesis:

\( H \): The dam just broke.

Not being at the dam, you can’t look at it and know directly. You must test \( H \) indirectly, that is, with the H-D method. To do this, from \( H \) you deduce an observable prediction, \( P \) – say this one:

\( P \): In minutes there will be a flood at place A.

The main river is a duct from the hypothesis to the prediction, amounting to the deduction of \( P \) from \( H \), logically embodying this if-then idea: “If the dam just broke, then in minutes there will be a flood at place A.” This is the design of the H-D test.

Next, suppose you see that a flood occurs. Thus the prediction is true, which corroborates the hypothesis. However, it does not absolutely prove it, because the dam may be intact (the hypothesis false) while some unexpected event up the shunt river – call it a “shunt cause” – possibly a great cloudburst, caused the flood.

But instead suppose no flood occurs. That makes the prediction false, and so the hypothesis must be false.
Figure 1. The logic of the hypothetico-deductive method, cast as a river system. Arrows in the rivers indicate the direction of flow.

While explaining the picture, the teacher encourages inquiries. Suppose a student asks, “What is the purpose of the shunt?” Responding with Socratic questioning, the teacher guides the class to realize that without the shunt, a hypothesis would be definitely true if its prediction were true, which is logically unrealistic.

Or suppose a student asks, “Are there good H-D test designs and poor ones?” Responding, the teacher Socratically guides the class to realize that a design that admits only a few kinds of shunt causes, and/or allows them to be controlled and made inoperative, is generally superior to a design that does not. For instance, with an actual flood at point A, the corroboration of the hypothesis would be more reliable if a check with the weather bureau revealed that a cloudburst hadn’t occurred in the shunt river’s watershed.

For further examples that relate the logic inherent in Figure 1 to H-D testing, see Romesburg (2009).

Case Studies in Designing H-D Tests

For a given case study, the teacher does the following. With several students in each group, (1) pose a research hypothesis, telling them it comes from a published report of H-D research (typically a journal), but not disclosing its source. (2) Ask them to design an H-D test of it (i.e., deduce from the hypothesis a prediction or predictions), and state how to experimentally determine whether it is true or false. (3) From information in the report, list for them the equipment and facilities they would have at their disposal, and the kinds of experimental manipulations possible. (4) If they get stuck during the exercise, Socratically facilitate their discovering how to advance. (5) When they have finished their designs, have them read the published report, learning its design and rationale, details of the experiment, and whether the prediction was true, corroborating the hypothesis, or false, disproving it. (6) In class, have the teams compare their designs with the published design and discuss respective merits and/or shortcomings.

Several such case studies, testing different hypotheses, will give the students a good working understanding of the H-D method.

An Illustrative Example about Bee Communication

The teacher selects and explains, say, the hypothesis from Nieh and Roubik’s (1995) article:

\[ H: \text{Bees feeding on sugar syrup located on top of a 120-foot tower in a forest can, on return to their distant hive, communicate the food’s location to foragers there that are unaware of its location.} \]

From information in the article, the teacher lists the equipment the teams should assume they would have available to carry out an H-D test of \( H \), and tells them what manipulations are feasible (e.g., capturing bees as they emerge from the hive and marking them by pasting identification numbers on the thorax).

They are to design on paper a test of \( H \), that is, deduce from \( H \) a prediction, \( P \), plan an experiment that would show whether \( P \) is true or false; and identify any shunt causes and ways of ruling them out with auxiliary experiments.

For this case study, there is only one realistic prediction, the one the original researchers thought of, and the students will come to it:

\[ P: \text{Bees recruited in the hive by foragers just returned from the feeder, and then captured and numbered as they leave the hive, should soon appear at the feeder after release.} \]

After the students present their designs in class for comment and critique, they read the source article, comparing its H-D design to theirs, learning that the hypothesis was corroborated.

The exercise can be capped off (as I do in teaching this case study) with the class watching the short, free online video “Bee Lines,” featuring actor Alan Alda (2003). His enthusiasm is catching as he interviews bee researchers in Panama while they recreate the article’s H-D test, explaining its rationale, such as how they experimentally eliminated the possibility that \( H \) was false but shunt causes were making the prediction true (e.g., bees from the hive learning the food’s location by following a scent trail left by returned foragers).

Case Studies in Designing & Executing H-D Tests

Occasionally a hypothesis can be found in a research report for which the students can design an H-D test of it, as above, then decide on the best of their designs, and for a class or club project carry out the test, the experiment taking moderate amounts of time and money.

An Illustrative Example about Plant Movement

Suppose the students are given this hypothesis:

\[ H: \text{The tip of Phalaris detects the direction of a light source and transmits the information to its lower parts, causing it to bend toward the source.} \]

After the teams have their designs, they present them in class. If any are faulty (e.g., contain an illogical deduction of a prediction from the hypothesis and/or fail to close off apparent shunt causes), the teacher encourages the students to rethink the designs until they reach a sound one. Such a design has four test predictions: (1) untreated (control) plants will bend toward a light source; (2) treated plants with tips removed will not; (3) treated plants with tips covered with opaque caps will not; and (4) treated plants with tips covered with transparent caps will.

Next, the class decides the experimental protocol for getting the facts with which to compare these predictions and, over some weeks, does the experiments. They discover that the four predictions are true, corroborating the hypothesis.

Then they are let in on a secret. They have redone research that Charles Darwin did on movement in plants. Have them critique...
Darwin’s thought processes by reading his report of his research (Darwin, 1880).

**Internet/Library Exercises**

Students’ understanding of the H-D method is incomplete unless they know its history. Thus, along with doing case studies, I recommend they do Internet/library exercises, like those suggested in Figure 2.

**Conclusions**

The chief merit of the river-system exercise is that it lends the H-D method’s logic a pictorial comprehensibility. Case studies with hypotheses drawn from the literature exercise students’ thinking in ways close to doing actual research; I regularly see students who have trouble memorizing excel in doing case studies. Yet which are pedagogically preferable: case studies where students design H-D tests but do not experimentally execute their designs, or those where they also execute their designs? In answering this, we should keep in mind that hypothetico-deduction is a logical method, not an experimental method, and that students learn its logic mostly through practice in designing H-D tests, not from experimentally doing the tests. Six or so hours of class time, say, allows for doing several case studies where students design but do not execute H-D tests, whereas the same time spent on a case of creating a design and executing it would ordinarily far exceed six hours.

Finally, case-study learning of the H-D method can also promote students’ appreciation of science as a wondrous thing: wonder at the knowledge generated by applications of the H-D method, and sometimes wonder at the scientists’ creative skills in designing H-D tests. Statistically speaking, might students who through case studies sense such wonder and become better at creating and thinking consequently become more serious students?

**References**


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