CASE TEACHING NOTES

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INTRODUCTION / BACKGROUND

The purpose of this simple, yet effective, case study (which is a particular take on the classic Black Box experiment) is to get students to make indirect observations, report these observations in a conference setting, and then conduct a peer review of research proposals. Ultimately, this exercise can be used to get students to think about atomic structure and how experimental evidence can be used to infer structure. I have used this case study in my first semester General Chemistry course (normally on the day before beginning discussion of atomic theory), although it could be used in other courses, for example as a lead-in to a discussion of the scientific method. The interrupted role-playing format of this case study works particularly well in a 75-minute class session; however, it has been used with success in shorter time periods.

CLASSROOM MANAGEMENT

I. The Research Group Study

Students should be separated into groups of three to four. Each group should choose a leader and also a group recorder. One copy of the Conference Invitation letter and the case study instructions (up to and including the section entitled "The Research Group Study") should be given to each group leader, who should share this information with his/her group. After each group understands the task at hand (that a description of the contents of *The Box* is required and that *The Box* may never be opened), each is given one *Box* sample to investigate. The sample is passed to each group member and the recorder makes a note of all observations.

The Box samples (one per group) should be small, nondescript, and sealable (i.e., once prepared, they should never be opened). I use small white shipping containers used by the Sigma Chemical Company; these have two metal clasps that prevent accidental opening. The contents of *The Box* should include several examples each of two or three different types of objects; these objects should NOT be household items. In the past I have used such articles as hard plastic spheres, porcelain figurines, large rubber septa, golf tees, etc. I encourage the individual instructor to be creative in selecting appropriate items, and recommend fabric shops and hardware stores as excellent sources for small unfamiliar pieces.

When choosing objects, keep in mind that the purpose of the exercise is circumvented if the student can jiggle the box and say, "Oh, that's a pencil."

There are several possibilities as to how each box is prepared. One possibility would have the same objects in each respective box (both in terms of type and number)—that is, all of *The Box* samples are identical. Another possibility is to have the same type of objects in each respective sample, with the exception that the number of *one* of the objects is varied in the different boxes—that is, some of the boxes are slightly different from others. This latter scenario can lead to a discussion of "isotopes" among the boxes.

The students are given an amount of time (10 to15 minutes) to collect raw data. I then announce that each group should begin to prepare a formal presentation of their research findings. Thus, their conference presentation (see below) should not simply list their observations. At this time I also announce that a third member of the group (i.e., neither the group leader nor the recorder) will act as presenter at the conference.

II. The Conference

The instructor, acting as conference chair, calls the "Thinking Inside *The Box*" Conference to order. Each group presenter in turn comes to the front of the class, introduces their group to the other participants, and then presents the results of their work. While these presentations are being made, the conference chair maintains on the board a list of relevant observations and other information from each group. Examples of two actual student presentations are given below.

> ***Group A:*** *Our group has found that the contents of* The Box *seem to be several objects of varied mass and volume. All of these assumed solids seem to cling together as if there is a possible magnetic charge. There are two larger objects. One has the ability to roll, and is the predominant weight of* The Box. *The other is a bit lighter and must have surfaces because of its reluctant ways to fall with the rest of the objects when the box is tilted. The smaller objects seem to have a jagged surface.*
>
> ***Group B:*** *Our group examined* The Box *using three senses: sound, sight, and touch. SOUND: The objects in* The Box *were loud and heavy. From these observations we concluded that the objects are solid and not hollow. There are more than one object by the way they hit against each other. The objects rolled around in* The Box*, so there are some round objects. SIGHT: By observing the size of* The Box*, we concluded that the objects are neither tennis nor golf balls, but smaller. TOUCH: When holding* The Box *and moving it back and forth, we realized that they [the objects] are not magnetic because they act as separate objects and bounce off each other. We can also conclude that the objects are made up of hard surfaces by feeling and hearing the contacts of the objects against the side of* The Box.

Once all of the groups have reported their findings, the conference participants are urged to discuss and analyze the collected findings. The following are questions I try to have considered during this time.

- Which observations are similar in nature? Are there consensus observations?
- Are these observations compatible with each other? Contradictory?
- Which observations are controversial?
- Which of these "observations" are actually hypotheses?
- What kind of observations may NOT be made?

- What, at this point, is a best description of the contents of *The Box*?
- Are all of *The Box* samples identical?

III. The Agency

At this point, the instructor can change hats and become Dr. Kasten from the F.B.I. (although, if possible, it is more effective to invite a colleague to assume this role). The solicitation for proposals is made and the students are given about five minutes to prepare brief proposals, which are again presented to the conference as a whole. Finally, the conference participants act as a review panel, each casting one "vote" for his/her favorite proposal. The two proposals with the greatest amount of support are funded (possibly receive extra credit). Examples of two actual student proposals are given below.

> ***Group C:*** *We plan to prove or disprove the hypothesis that the components inside* The Box *are magnetic by sliding a magnet across* The Box *and observing if the objects move in the direction of the magnet or not.*
>
> ***Group D:*** *We propose that* The Box *be thoroughly researched by means of radiographic imagery, which will show us the sizes and approximate shapes on a two-dimensional film. Metal objects will appear bright white and we will be able to tell the approximate densities in order of least to greatest by these means. We would like the same type of setup as an airport because it would be inexpensive, [and would] take a lot of wear and tear.*

Very often one or more groups will suggest taking *The Box* to the local airport so that it can be examined using x-rays. This leads to two interesting topics. First, the question of whether this should be considered "looking" in *The Box*. And second, the nature of spectroscopy. Both of these are nice lead-ins to a discussion of atomic structure and how we "know" what an atom looks like.

A Final Thought

Some would suggest that students should be able to open up their *Box* samples at the end of this exercise so that they might see how close their observations match the actual contents. I would argue strongly against this as it reinforces a false impression that many students have as to the nature of scientific inquiry; that for any problem there is "an answer in the back of the book." Our knowledge of the inner structure of the atom, for example, is not based on "looking" at these structures (you can't photograph an atomic orbital), but rather on an accumulation of indirect experimental evidence. More importantly, though, by leaving the question unresolved a student may continue to think about it for some time to come. I knew that this exercise had been a success when a student walked into my office, two years after taking General Chemistry, and announced, "You know, I'm still wondering what's inside that *&*@% Box*."

Acknowledgements: This case was developed with support from The Pew Charitable Trusts as part of a Case Studies in Science Workshop held at the University at Buffalo, State University of New York, on May 20-24, 2002.

Date Posted: 11/15/02 nas