# The Real Prize Inside: Learning About Science and Spectra from Cereal Boxes

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Opportunities to learn are everywhere, often in overlooked places, such as in the Universal Product Code (UPC) that is used for barcodes on nearly everything we buy. In this paper, we describe an engaging and meaningful activity in which these barcodes were used in an introductory calculus-based physics class.

Our goals for this activity were twofold. First, we wanted to provide students with an intuitive introduction to a unit on atomic spectra by connecting it to something that they see in their everyday life. The second goal for this activity was to help students understand the nature of scientific inquiry. Students entering physics classes often have an inaccurate and persistent perception of science as dull and an enterprise for "smart" people, and of science classrooms as places where one merely memorizes equations.[1-3] Both the physics and science education communities have tried to address these issues by providing students with opportunities to "do science" in the classroom. The activity described here gives students a chance to see science as a process that involves identifying, describing, and testing patterns in the world around us, as well as an opportunity to carry out those tasks with a familiar phenomenon they know little about.

While we utilized a college SCALE-UP environment,[4,5] this activity could easily be adapted for a high school or more traditional college classroom. We spent about 20 minutes engaged in this activity, but depending on the context and purpose(s), it could be shortened or lengthened to change the difficulty or depth.


**Fig. 1. Barcodes provided to groups for the purpose of identifying patterns.**

## Cracking the Code

To facilitate group activities, a SCALE-UP classroom contains round tables that hold nine students each (three groups of three), and the students are accustomed to group work. However, since this activity was unlike many of our everyday lessons, we prefaced it with a comment that what they were about to do might seem unconnected to physics, but they would

**Table I. Key patterns and hypotheses about the Universal Product Code.**

- All the barcodes are black and white.
- Every barcode begins and ends with two longer bars.
- There are two sets of five digits separated by another set of longer bars.
- The codes for identical numbers located to the left and right of the longer middle bars are different.
- Each code starts with zero (see article for discussion of this hypothesis).
- The first five digits are the same for the same manufacturer.
- There was a separate digit at the end (most notice the digit, but no one discerns the underlying checksum algorithm).

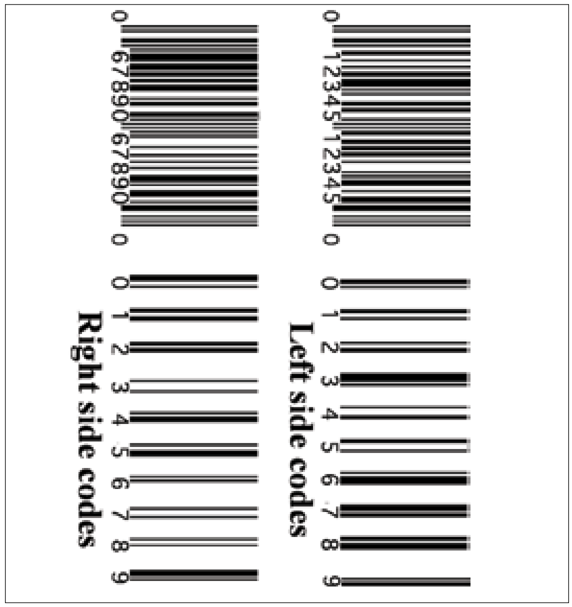


**Fig. 2. The right and left side codes for the Universal Product Code. For more information, visit Queen's University site http://educ.queensu.ca/~compsci/units/encoding/barcodes/undrstnd.html.**

eventually understand the connection to both the current topics in class and to the nature of science as a process.

Each group was initially handed a set of four UPC barcodes (Fig. 1), specifically chosen to highlight some of the key patterns of the code (Table I). We asked each group to make a list on a small whiteboard of their observations and hypotheses about the Universal Product Code using only the barcodes we gave them. As the students worked, we (the course instructor and two graduate teaching assistants) circled the room asking questions and encouraging groups that were struggling.

After each of the groups created its own list, the instructor compiled a master collection of observations from the different groups. Though the individual lists were different with a great deal of overlap, the class as a whole was able to identify almost all of the key features listed in Table I. Some data seemed trivial, like the black and white nature of all the barcodes. Other data were harder to identify, such as the checksum digit at the end of each code. Many students recognized that the first five digits for the two Quaker Oats® products were the same and speculated that those digits might indicate the manufacturer.

One of the observations produced an ideal forum for talking about the nature of scientific inquiry: every barcode in the activity began with zero. This observation prompted some students to state a general rule, "Every barcode begins with zero." We used this as an opportunity to discuss the difference between observations and hypotheses: the students "observed" that all of the barcodes they had been given started with zero and they "hypothesized" that all barcodes everywhere must begin with zero.

A discussion on the nature of scientific "proof" developed naturally. The instructor asked what it would take to disprove the hypothesis that all barcodes begin with zero. Some students then started checking various objects in their bookbags, trying to find an item with a barcode that did not start with zero. After discovering the barcode on the back of their textbook began with "9," the class suggested a revised hypothesis: food item barcodes begin with zero. The instructor was then able to point out that while it can take very little to disprove a hypothesis (one barcode that did not start with zero), it is impossible to "prove" a hypothesis. Rather, hypotheses, as well as theories and models, are continually tested and refined, becoming more accepted as they withstand tests and accurately predict phenomena.

One of the features that we did not discuss at length

**Fig. 3. Blank codes to which the students applied the Universal Product Code: (a), (b), and (c) correspond to the group that received the barcode.**

**Fig. 4. Barcodes provided for students to check their work: (a), (b), and (c) correspond to the group that received the barcode.**

was the checksum digit, which is the last number in each code. We mentioned how it could be used to validate a scanned number, but we did not go into the calculations behind its use. Along with a comment that scientific research often produces more questions than answers, the question of the checksum digit was left as an exercise for interested students (the information is quite easy to find on the Internet).

This part of the activity could easily be extended and made more challenging by asking students to use various products in their home or dorm room to figure out the line patterns for each number. As just noted, they could also do research on how the checksum is generated, perhaps coming up with a spreadsheet to calculate the checksum digit for an arbitrary UPC sequence.

## Deciphering the Message

Once the class agreed on a fairly comprehensive list of hypotheses, we gave every group the actual bar pattern for the left and right digits (Fig. 2). Each of the three groups at each table were also given a barcode with no numbers (designated a, b, and c in Fig. 3). We asked them to use the patterns to determine the product code for their barcode and then to compare their work with the other groups at their table to identify similarities and differences. The groups discovered that one barcode had the same first five digits as the Kellogg® barcode we had given them earlier and thus concluded that it must be another Kellogg® product. The other two barcodes shared the same first five digits and so probably came from the same manufacturer (General Mills® in this case). Finally, we gave them the complete barcodes, including the manufacturer and product information (Fig. 4). This gave them the chance to check their work and become more confident in their hypotheses.

The instructor wrapped up the entire activity with a class-wide discussion of its purpose. We explained that science endeavors to identify and describe patterns in the world around us; it then tries to explain the origins of those patterns, tests hypotheses, and revises them through predictions of similar phenomena. We restated the class hypothesis about the leading zero and recapitulated the discussion of how they were actually "doing science" in their treatment of that hypothesis.

During this post-activity discussion, several of the groups talked about the UPC as a "thumbprint" for a product, and some students asked if and how this was related to atomic spectra, perhaps because they had seen that topic on the course calendar. This provided a perfect stepping stone to introduce spectra in the context of an observation from everyday life. They could think of spectra as identifiers for the elements just as the UPC barcodes are identifiers for a product—a way to recognize each using nothing but a set of lines in specific patterns. In light of this activity, we even had the chance to talk about the discovery of helium on the Sun before it was located on Earth.

## Finding the Prize

This activity provided students with a connection between atomic spectra and an easily overlooked occurrence from their everyday life. Perhaps even more importantly, it gave them a chance to engage in scientific inquiry in a fun and meaningful way and created the space to discuss the process of science.


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