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The Three Kinds of Light

1 What is Science?

Answer the following four 'Optics' questions correctly and you can go on to the next round of the Academic Decathlon to represent your school at the forefront of science:

Question 1: What are the three kinds of light?

Question 2: What is it called when an object loses its electric charge?

Question 3: Light is reflected at a _____ angle from a rough surface (fill in the blank).

Question 4: What is the opposite of an electric motor?

These are 'Optics' questions from the workbook for the high school Academic Decathlon of last year. I was asked by C., a young friend who was a student at a large (>4000 students) public technical high school in Chicago, to help their team prepare. Optics was baffling them, and their coach was an English teacher, and he was having a hard time with the questions as well. Science (sic) seemed illogical and arcane; they felt it was obviously a different world, and one that they were not cut out for (these were bright kids, as most are).

2 C., An Eighth Grader

I had met C. through Lourdes Monteagudo, the Director of the Teachers Academy of Mathematics and Science (TAMS) in Chicago. Lourdes had just come back from an 8th-grade graduation in a public school in one of the roughest neighborhoods in Chicago, and where she had been bowled over by the speech of the valedictorian. I asked his name, and hired him for the summer to work with us on the CDF experiment at Fermilab (of top quark fame- in fact that was what I was working on at the time).

C. comes from the far South Side in Chicago, from a neighborhood known best, unfortunately, as the home of 'Yummy', the 14-year old who shot an 11-year old as a contract killing for his older gang leaders. I would often find him in my lab late at night doing homework; he said it was 'easier' to go home after everybody at home was asleep.

In high school C. decided on a Science Fair project based on work he had done the previous summer with me on cross-talk in the long multichannel cables we use in the trigger electronics for CDF. The cables are custom, with a relatively high impedance and 10 sets of twisted pairs. The question was how much cross-talk there was between individual pairs. One brief story- I left C. alone with a modern digital Tektronix scope, asking him to see if he could figure out how it worked (I'm much happier with an old analog 454- I never can tell with the new ones whether I'm really looking at the signal or accessing storage and seeing an old one). I came back half an hour later to see how C. was doing, and he said 'fine. I found the instruction manual on the web and printed it out, and I think it's pretty easy.' (He had a trace, and the scope was triggering on a signal happily).

But now to the second point. When C. presented his project to the science teacher, the teacher said 'What do *you* know about cross-talk?' So C. then gave the teacher his written report on cross-talk from the summer, and the teacher said 'No kid should know that much about cross-talk', and wouldn't let him submit the project or be in the Science Fair. As C. said, the teacher said 'I had an attitude' (Chicago-ese for uppity).

3 D.

A second anecdote about the real problems bright curious kids have in urban schools. Every year I used to invite the local 4th graders to the University where I'd put on a 'Lecture Demonstration Spectacular'. Hellmut Fritzsche, when he was Chair of the Department, had instituted the Spectacular as a way of showing the Faculty the depth and breadth of the Departmental lecture demonstrations, which are the product of a first-rate staff. I had done this in a number of years, and so it seemed natural to repeat the show for my kids' class. It was so popular that I kept it up for a number of years after my kids had left the 4th grade.

One of the demonstrations was to roll two cans of soup, one pea soup, and the other beef bouillon, down an inclined plane. I'd tell the kids about the soup, and then ask them which would roll fastest. Usually the majority voted for the pea soup, as it was 'heavier'. We'd then do it, and lo-and-behold the bouillon would win.

I'd then show them that it didn't have anything to do with heavier- we'd take a wooden hoop and a wooden disk of the same diameter, and I'd show that they weighed the same on a simple balance. I then asked which would go faster, and this was a harder question, usually with no clear consensus. On doing it, the disk would win handily.

One year, I did this early in the Spectacular, and said 'see- it's like the soup', as usual. Forty-five minutes later a little pudgy black kid in the front row raised his

hand, and said 'I have a question. You said that the disk won because it was like the soup, but the pea soup is like the disk and the bouillon is like the hoop. I don't understand what you meant.' A teacher rushed up and said 'D., be quiet', and then apologized to me (in front of the kids): 'He's a trouble maker, Professor Frisch, don't mind him.' D. had sat there for 45 minutes thinking about this, and then decided to ask. He clearly had an attitude. He also wasn't into science.

4 To Be Continued

This has been anecdotal, to use a favorite word of my UC colleagues in the social sciences. However there's one important fact: we now have solid assessment numbers from TAMS showing that there are methods to change how math and science are taught that work on the scale of the 400,000 students in the Chicago Public School system. And so to make it short, I would like to list some of my more general observations.

- I like 3rd and 4th graders. They are still curious, and they have the real scientific instincts for thinking, asking, testing, and observing. It hasn't yet been beaten out of them, and the fear teachers have of science hasn't yet been transmitted to them. Identifying the really talented ones early can by done; they're there, and one only has to look to find them. K-8 is where kids are programmed to do well or poorly in math and science; high school is important, but cannot succeed if the elementary schools fail.

- Keeping kids from being done in as they grow older is much harder; it's not a question of curriculum alone (although having a curriculum teachers are comfortable with is an essential element- take a look at Howard Goldberg's wonderful TIMS modules). A critical element is the occasional bad teacher. Kids are proud, and, from watching my own, won't play a game in which they're set up to lose. One year of a teacher who is on a kid's case can be enough to undo the work of many good teachers. Getting rid of the teachers who attack a curious kid's self-esteem is one of the most important aspects of good urban math and science education.

- What science *is* is a mystery to most teachers. In Chicago there aren't specialists; there are 17,000 teachers who teach math and science on a regular basis. There is a heavy emphasis on memorizing names; science is seen more as a body of knowledge than a mix of curiosity and method. Teachers consequently avoid it, and their uncertainty is transmitted to the kids. In the early grades, quantitative work as in the TIMS program mixed with curiosity-driven questions can really turn kids on. A physics department can have a big impact on local schools with a rather small investment by each person if grad students, postdocs, and faculty make regular visits. There are a lot of us.

- In a presentation to the American Physical Society Council one evening at an APS meeting it was stated that 'We do not know how to deal with the problems

of math and science education in the big urban schools.' I truly believe that we *do* know many if not most of the ingredients, and have working models for how to confront and solve the problems. We need to move as a community away from a narrow view of these problems to dealing with them on a large scale.

It made a big difference to the kids at the high school I visited to be told that there are *not* three kinds of light, and that it wasn't them, but the questions that were 'stupid'. Even more important to them, on the first visit I had brought along an undergraduate from UC who had been in the Academic Decathlon, and she told them something even more basic to getting good grades in 'science' classes. This was that each of these questions had the answer in the workbook, and that the way to study for the Decathlon wasn't to think, but to make flash cards that gave the answers (she also talked with the girls in the class at length, telling them that women can be scientists, and can go to college and major in science. They had never met a scientist before.).

The correct answer to 'What are the three kinds of light?' is: 'Neon, fluorescent, and incandescent'. It's in the book. You can look it up. In fact, you'll have to- you'll never figure it out on your own. [1]

[1](Answers I: My answers to the 4 optics questions were, in order 1) I have no idea- there's only one kind of light. 2) A shame...?; 3) again, no idea- it reflects at all kinds of angles (the kids in fact said this to me, and were puzzled by the question's implication that there was a single word that described this); 4) A horse? (again, no idea)

Answers II: The 'correct' (sic) answers were: 1) neon, fluorescent, and incandescent (yes, the question was worded as above); 2) a discharge, 3) A 'diffuse' angle, and 4) an electric generator.