The Magic of Science Through the Science of Magic

Nathaniel Lasry
John Abbott College, Sainte-Anne-de-Bellevue, Québec, Canada
lasry@johnabbott.qc.ca

Abstract

Magic tricks produce awe and wonderment. Why not use magic as a pedagogical approach? This paper presents the magic of science through the science of magic.

Abracadabra! Have you disappeared? Well, if the text below has not disappeared and you're still interested in adding a little magic to your courses, this paper might be just what you're looking for. In this paper I will share with readers the fun of creating and using magical demonstrations. To be able to use magic in your classes, I will show a simple way to convert good in-class demonstrations into awesome magic tricks. To illustrate the procedure, I'll describe how I transformed a couple of classical demonstrations into magic tricks that I have presented in classrooms and to many groups of science teachers.

Thwarted Expectations

Lady Astor is said to have once told Sir Winston Churchill: "If I were your wife I would put poison in your coffee!" To which Churchill answered: "If I were your husband I would drink it!" Churchill's reply is funny mainly because it is so unexpected. Thwarted expectation can give rise to interest and humour. Think about that B movie where the end was so predictable; not so interesting. Magicians make spectacular uses of unexpected events. Where does that leave the science teacher?

Good science demonstrations also reveal things that are unexpected. For instance, the outcome of a demonstration can be unexpected because of some student misconception. One knee-jerk reaction may be to explain away any misconceptions; but that may result in a demonstration that becomes expected or predictable. The magic proposal is different. Teacher-magicians build up an expectation and use the unexpected observation to engage students and maybe even feign magical powers. These magic tricks require no sleight of hand: the trick is only in the heads of those who find the demonstrations unexpected. There are many common misconceptions in science (Halloun & Hestenes, 1985; Hestenes, Wells, & Swackhammer, 1992; Vosniadou & Brewer, 1992) that result in a variety of possible unexpected observations. This means that many of these demonstrations that result in unexpected observations can be dressed up as magic tricks.

Why Modify Demonstrations?

A demonstration can liven up a lecture. Students seem to perk up and pay closer attention. However, a study conducted at Harvard suggests that students simply observing a demonstration learn no more than those who have not seen the demonstration at all (Crouch, Fagen, Callan & Mazur, 2004). To be effective, students must be actively engaged during the demonstration. Effective demonstrations engage students by requiring them to make predictions about what will happen before they see the demonstration (Sokoloff & Thornton, 2004). Students become engaged and usually develop a vested interest in the outcome (i.e., "will I be right?"). If the outcome differs from their prediction, students pay closer attention to the outcome and try to figure out why they were wrong.

Magic demonstrations engage students differently. Instead of asking students to predict the outcome, the magician-teacher builds the demonstration around an incorrect expectation. Magic demos build on this incorrect expectation to maximize the effect of the unexpected observation. When the tension and drama are properly built into the trick, students become engaged: they pay close attention to the unexpected outcome and will try to figure out what is happening.

Making a Demonstration Magical

Two demonstrations are now presented: the double conic roller demonstration (center of mass) and the disappearing Pyrex in mineral oil (refraction). While these demonstrations may be familiar to seasoned teachers, the purpose here is to show a different mode of presentation; that is, not to sell the "salad" but its "dressing."

The Double Conic Roller

Among the great center-of-mass demonstrations available from most laboratory equipment providers is the double conic roller that is placed on an inclined wedge (Figure 1). When a pen is placed on the high side of the wedge (the left side in Figure 1), it rolls down the incline. However, when the wooden double cone is placed on the lower side of wedge (the right side in Figure 1) it rolls "up" the incline! How does that happen?

Figure 1. The double conic roller. The pen rolls down the incline from left to right. However, the double cone rolls from right to left, sinking inside the wedge.

The center of mass (COM) of both objects actually goes downwards as they roll. The COM of the pen follows a path parallel to the surface of the incline. However, the COM of the double cone is higher where the wedge is narrower (on the right in Figure1), even though this seems to be the lower end of the incline. The roller "sinks" into the wedge because the wedge becomes wider as the cone moves from right to left in Figure1. This gives the impression that the double cone rolls up the incline. In fact, it is rolling down into the wedge. Both objects fall in opposite directions: the pen moves down along the incline while the double cone seems to move up the incline (but really sinks into it).

Dressing up the demonstration as a magic trick. The inclined wedge and double cone are shown to the class. The cone and wedge are handed to 1 or 2 students for inspection, to make sure that there are no gimmicks (students often look for magnets). The teacher-magician shows students that one side of the inclined wedge is higher and lets a pen roll down from the top of the incline. With a deep breath and tremendous concentration, the teacher-magician explains that, with the mind's power, telekinesis will be performed, and the double cone will be dragged up the incline, against gravity! (Drum roll…) The double cone is then released from the lower end of the incline and it rolls "up" the incline!

As the double cone proceeds up the incline, the instructor's hands precede it as if magically pulling it upwards. When the double cone reaches the top, the instructor needs to quickly pick it up, because the "trick" would be spoiled if the cone just stayed there for some time. A long sigh is released, indicating that a tremendous mental effort was expended.

Students usually ask that this trick be performed again. The trick should be repeated once or twice, so that students can shift their focus to different aspects of the demonstration. Students often offer hypotheses (i.e., proposed explanations). These can be explored or systematically tested. The class is asked to debunk the trick through a structured inquiry process.

Deconstructing the demonstration. In this demonstration, a pen is rolled down an incline to show that one side is higher than the other. However, because the incline is also wedge-shaped, the lowest point for the double cone is inside the wedge. This demonstration forces students to rethink the concepts of high and low. The direction an object falls is only related to the path of its center of mass, not the contact surface it rolls along. Thus, two objects on an identical surface may have different "highs" and "lows" and may therefore fall in different directions. This observation is sufficiently interesting and unexpected to get students to wonder and ask about how things fall.

Pyrex and Mineral Oil: Now you see it, now you Don't

A Pyrex rod or test tube disappears when submerged in mineral oil because both have highly similar refractive indices. The same Pyrex tube is clearly visible in a beaker of water. Usually, this demonstration is used to illustrate the concept of refraction (or lack thereof) after the topic has been introduced.

Figure 2. A Pyrex rod becomes invisible when submerged in mineral oil because Pyrex and mineral oil have highly-similar refractive indices.

Dressing up the demonstration as a magic trick. A relatively-large beaker containing mineral oil is displayed. The instructor adds some more oil from an unidentifiable bottle while telling students that this is a "magic" liquid: This liquid binds broken pieces of glass back together!

The teacher-magician takes a Pyrex test tube and, after carefully wrapping it (usually in thick, brown, lab paper), proceeds to shatter the tube with a hammer. The teacher-magician then pours the Pyrex fragments into the beaker with magic liquid that, unbeknown to students, has a hidden, intact Pyrex tube submerged. The teacher-magician stirs and pulls out a fully "repaired" Pyrex tube! Note that, depending on the length of available test tubes, these may need to be first shortened by cutting to allow one of them to be fully immersed in the oil.

Note that a pair of tongs is necessary to navigate the sharp fragments and grasp the previously-inserted whole test tube. When the seemingly repaired Pyrex tube is pulled out, students are asked what they think: is it possible? Students usually volunteer explanations that can be tested. They are then guided through an inquiry cycle where the concept of refraction is constructed and the magic trick debunked.

Deconstructing the demonstration. Disappearing tricks are the bread and butter of professional magicians. What makes an object visible is the way it reflects or bends light. This demonstration shows that if two objects bend light in the same way (i.e., they have similar indices of refraction) then you cannot tell them apart. Most students do not believe that stirring Pyrex fragments in a fluid will weld them back into place. It is useful to combine the unexpected observation with students' incredulity as a means to explore what really happened and introduce the concept of refraction.

Summary and Conclusion

Many classical demonstrations can be turned into magic tricks. The first thing to do is to find a demonstration that is interesting because it produces an unexpected observation (e.g., lying down on a bed of nails will not hurt you). Then teacher-magicians can build up an expectation (e.g., nails are sharp, dangerous objects: pretend fearing nails, drop an apple on a bed of nails and pull it out punctured). Playing-up an expectation maximizes the effect of the unexpected observation. Finally, perform the magic demonstration (e.g., lying comfortably on a bed of nails) and wait for students to start asking questions!

I often view my mandate as a science teacher quite broadly: My goal is to get students to ask about the world that surrounds them. As best put by Marcel Proust, "the real voyage of discovery consists not in seeking new landscapes but in having new eyes." Like most science teachers, I take great joy in seeing students wonder and ask about the simple things most people take for granted. Magic is my preferred way to get students to wonder and ask about simple things.

References

Halloun, I. A., & Hestenes, D. (1985). Common-sense concepts about motion, *American Journal of Physics*, *53*, 1056.

Hestenes, D., Wells, M., & Swackhammer, G. (1992). Force concept inventory, *The Science Teacher*, *30*(*Issue number?), 141.

Crouch, C., Fagen, A. P., Callan, J. P., & Mazur, E. (2004). Classroom demonstrations: Learning tools or entertainment? *American Journal of Physics*, *72*, 835.

Sokoloff, D. R., & Thornton, R. K. (2004). *Interactive lecture demonstrations: Active learning in introductory physics*. Hoboken, NJ: John Wiley.

Vosniadou, S., & Brewer, W. F. (1992). Mental models of the Earth: A study of conceptual change in childhood. *Cognitive Psychology*, *24*, 535.