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Finalist Essay

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Critical and Scientific Thinking in the High School Classroom

In my classroom, I utilize many non-fiction science books published for general audiences. I refer to many more as part of my presentations and even have a “book of the week” that relates to our lessons in some way. There is, however, one book that stands out. I use the entire book and my lesson was actually built around the text. The book is *Don’t Believe Everything You Think: The 6 Basic Mistakes We Make in Thinking* by Thomas Kida.

As part of the first unit in both of my high-school science classes, Environmental Science and Chemistry, I cover the scientific method. This is a subject that students have covered extensively. They are usually juniors and seniors (with an occasional sophomore or freshman) so they know by heart the "steps" of the method, but they do not truly know what it means to think like a scientist. They are not used to dealing with the common thought processes that scientists strive to overcome. Using Kida’s book as a basis, I present the topic in the form of a quiz, having the students fill out an answer sheet for the test.

The lesson is a PowerPoint presentation with additional material over two days, covering three fallacies each day. For each of the six fallacies of thought presented by Kida, I start with quiz questions designed to illustrate the fallacy.

The first fallacy is: People prefer stories to statistics. There is a saying that I have on my wall: “The plural of anecdote is not data.” Almost all pseudosciences are anecdotal. Most students get the questions, which are concerned with violent crime and school violence, wrong initially, but they do understand why perception and reality differ. The strongest examples of this fallacy are the grandparent who has smoked for sixty years but remains as healthy as a horse and the extreme cold snap during winter. Both are very powerful stories, but neither have any significance negating cancer rates among smokers or global climate change. I relate the impact of the media, including the media's biases in shaping public view.

The second fallacy is: People seek to confirm, not question, ideas. The popular perception, which science teachers often fail to correct, is that experiments are designed to “prove” a hypothesis. It is easy for non-scientists to fall into the trap of looking only for evidence to support a hypothesis or belief and fail to see facts which disprove that idea. The conspiracy theories surrounding 9/11 and John F. Kennedy are examples of this fallacy. I use a puzzle where I present three numbers to the students (2, 4, 6) and tell them they need to deduce and be certain of the rule behind the numbers. They can give a set of three numbers and I will tell them if their numbers follow the rule. Most people follow the same pattern (usually giving three consecutive even numbers) and do not really test the assumptions they made; they name more sets that follow their assumed rule. I relate this rule to a scientist’s attempt to falsify, which is the key to good experimental design.

The third fallacy is: People do not understand the role of chance and coincidence in life. The basic idea is that, given enough opportunity, events with even very low probabilities **will** occur. Synchronicity is simply an illusion of our mind attempting to put order to random events. There is a popular story of the nurse whose life was saved by a young man who knew CPR, which he learned because that same nurse had saved his life with CPR seven years earlier. Given, however, the number of lifesaving events in the world every day, it is inevitable that this coincidence would occur. Most copies of this story also fail to note the other connections between the nurse and the young man, which would have influenced the two being together at the same time and place. I try to illustrate this fallacy using coin flips and other chance occurrences; especially games of chance because we are less than a mile from a casino. Most students seem to understand the basics and no one falls for the multiple coin flip questions, regarding the chances of getting a "heads" on any particular flip, even if there has been a long string of "tails." I use this to introduce the Gambler's fallacy (past performance affects future events for independent trials) and the bell curve.

The fourth fallacy is: People misperceive the world around them. This fallacy covers both the tendency to ignore contrary evidence and pattern-seeking behavior. The human mind is pre-programmed to seek patterns, a helpful trait that can be easily tricked. Spiritualism and psychic phenomenon are pseudoscientific examples of this fallacy. People see random patterns as ghostly figures. When told a location is haunted, people are very likely to interpret events differently than those who are not told this. To illustrate this fallacy, I use the "Paris in the spring" trick, optical illusions, and the "basketball pass" videos listed below. This is easily the part with the greatest impact. Students often accuse me of cheating on test questions and are shocked at the results of the video. I use this to relate pattern-seeking behavior and pareidolia. For those familiar with the basketball videos, no explanation is needed. For those not familiar, I recommend going to these websites:

- Visual Cognition Lab: http://viscog.beckman.illinois.edu/flashmovie/15.php
- The Monkey Business Illusion: http://www.youtube.com/watch?v=IGQmdoK_ZfY

The fifth fallacy is: People over-simplify. In practice, this fallacy most often refers to shortcuts in thinking like stereotypes. It can also refer to the error of failing to look deeper into relationships and causation. I use two questions to introduce this fallacy. The first question lists characteristics that are statistically unrelated to a profession but are part of a stereotype (the quiet librarian and the obnoxious, over-the-top salesman) and the second question is the classic "lost dollar puzzle":

> Three men are traveling together and check into a hotel, sharing one room. The desk clerk charges them \$30 and each pays \$10. A little later, the desk clerk realizes he has over-charged them, as the room is only \$25 for the night. He gives the bellboy \$5 to take back to the men. The bellboy decides that \$5 cannot be divided by the three men, so he only refunds them \$3 (meaning each has paid \$9) and keeps \$2 for himself. If each man paid \$9 x 3 =

$27 + $2 to the bellboy = $29. What happened to the other $1?

Students do not seem to link this to scientific thinking as easily as the other fallacies. To help show how this fallacy applies to science, I introduce the idea of correlation and causation with a graph of pirate population (decreased) and global temperature (increased) since 1700, indicating that a lack of pirates causes global warming. The increase in Somali pirates corresponds to a slight decrease in temperature during the last five years, further lending credence!

The sixth and final fallacy is: People have faulty memories. I start with a 15-word memory test and in every class I have 1-2 students who swear I cheated because a word they clearly remember being on the list is not there. There are many of these word lists available online, but they are all designed the same way, missing some word that CLEARLY fits with the others on the list. I have also used an eyewitness test (less successfully) where teacher "A" interrupts class but I refer to teacher "B" as the interrupter. I relate this to the concept of selective memory and selection bias in such things as psychics and scientific experiments. To further illustrate the concepts, I have a "Millennium prediction" issue of a popular tabloid that has top psychics making predictions. We compare the hits and misses from this printed record. I also show a YouTube video demonstrating cold-reading techniques.

The fall semester of 2010 was the second year that I have used this book with my classes. While some of the demonstrations worked well, others were and are in need of change and I have updated some for this year and I will be updating others for next year. It has, however, made enough of an impact on my students that many of them repeat these fallacies throughout the year and remark on them when we encounter examples throughout the course. This ability to apply these principles of thought in new situations, rather than a rote memorization of a series of numbered steps, is the focus of my teaching of scientific thinking. This produces, I believe, critical thinkers who evaluate what they see, hear, and are told.