Science Stories:

Using Case Studies to Teach Critical Thinking

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Introduction

Clyde Freeman Herreid

Critical thinking is like Mark Twain's quip about the weather—everybody talks about it, but nobody does anything about it.

Teachers are fascinated by facts, esoteric minutiae that beguile, tantalise and titillate their fancies. They spend their time in the classroom trying to convince students to appreciate the same ideas. Yet when you ask teachers what they prize most, they will say critical thinking. They claim they want this most of all in their students—the ability to reason (Yuretich 2004). But teachers love their Krebs cycle, Henderson-Hasselbalch equations, tooth formulae, digestive enzymes, hormones, bones and scientific nomenclature too much to give them up. Nor would I want them to. But let's face the facts: they are not teaching critical thinking.

Most teachers cannot define critical thinking. To take only one example, in 1995, the California Commission on Teacher Credentialing and the Center for Critical Thinking at Sonoma State University initiated a study of college and university faculty throughout California to assess current teaching practices (Paul, Elder and Bartell 1997). Of the faculty surveyed, 89% said critical thinking was a primary objective in their courses, but only 19% were able to explain what critical thinking is and only 9% were teaching critical thinking in any apparent way. Furthermore, 81% of the faculty believed that graduates from their departments acquired critical-thinking skills during their studies, but only 9% could articulate how they would determine if a colleague's course actually encouraged critical thinking.

Experts do not really agree on a precise definition of critical thinking. But I like Moore and Parker's (2004) approach that critical thinking is the careful, deliberate determination of whether one should accept, reject or suspend judgement about a claim and one's degree of confidence about one's position. So, critical thinking involves evaluating evidence and examining relevant criteria for making a judgement. It involves logic and clarity, credibility, accuracy, precision, relevance, depth, breadth, significance and fairness in dealing with an argument. These are the topics of textbooks on critical thinking. Major emphasis is placed on informal logic (often said to be equivalent to critical thinking). Informal logic deals with analysing and evaluating arguments and addresses how to avoid many of the major mistakes that humans can make. These qualities are said to constitute critical thinking.

To varying degrees, all of these qualities are desirable for anyone, not just scientists. But can they be taught, and how best to do so? We make the argument in this book that such habits of mind can be taught and case studies are one avenue to achieve this end. In the chapter "The 'Case' for Critical Thinking", David R. Terry brings the critical thinking literature to bear on this issue.

Another approach to critical thinking is seen in Bloom's 1956 taxonomy of "learning domains" in approaching problems. The cognitive domain is especially relevant. Bloom and his team ranked learning in a hierarchy, starting with simple knowledge at the bottom, then comprehension, application, analysis, synthesis and evaluation at the top of a pyramid. Bloom's original domain arrangement is shown on the pyramid in Figure 1. Anderson et al. (2001) revisited the categorisation and produced the arrangement on the right in Figure 1. The differences are small. The new version has translated the original terms into action verbs and switched the order of the top two domains.

Where does critical thinking fit into these schemes? For our purposes, critical thinking corresponds to the learning categories on the upper part of both diagrams. In contrast, in traditional science courses taught by the lecture method, the focus is on the lower part of the pyramids. Students are asked to remember facts, terms and concepts—hardly critical-thinking exercises. In contrast, the upper part of the pyramid—which deals with application, analysis, synthesis and evaluation—fits squarely in the critical-thinking camp. So the first goal of this book is to provide a way for teachers to enhance student skills in these areas. But as cognitive scientist Daniel Willingham (2009) points out, critical thinking cannot be taught with abstract exercises. It must be taught in the context of a discipline. Critical thinking in art, music, English literature or history is not the same as it is in natural science.

What, if any, are the unique features of critical thinking in science and how do case studies help teach these skills? I argue that it boils down to that hoary chestnut, the scientific method. Recall the steps of the classic scientific method (sometimes called the hypothetico-deductive method): We ask a question, propose a hypothesis to answer the question, devise a test or experiment to test the hypothesis, collect the data from the test and reach a conclusion. With repeated iterations of the process, the question is solved and science marches on. In Kathy Galluci's chapter "Learning About the Nature of Science With Case Studies", she examines the nuances of the method in detail. You will notice that much of this process is not special. People ask questions and make guesses all the time. But few of us ever do much testing and retesting to see if the data we collect are consistent with our hypotheses. This single feature is the essence of the scientific enterprise and the essence of critical thinking in science. Yes, science is a collection of facts and principles about the physical world, but what is essential to us is that it is a *way of knowing*.

Consequently, if we want to teach students about science, we need to do two things: give them science content and teach them the critical-thinking skills that scientists use. We need our students to have a good grounding in science content so they will be able to ask intelligent and relevant questions, suggest hypotheses and know how to interpret data to reach reasonable conclusions that are consistent

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Chapter 5

Childbed Fever: A 19th-Century Mystery

Christa Colyer

The Case

Part I

Ignaz Semmelweis, a young Hungarian doctor working in the obstetrical ward of Vienna General Hospital in the late 1840s, was dismayed at the high death rate among his patients. He had noticed that nearly 20% of the women under his and his colleagues' care in Division I of the ward (the division attended to by physicians and male medical students) died shortly after childbirth. This phenomenon had come to be known as "childbed fever". Alarmingly, Semmelweis noted that this death rate was four to five times greater than that in Division II of the ward (the division attended by female midwifery students).

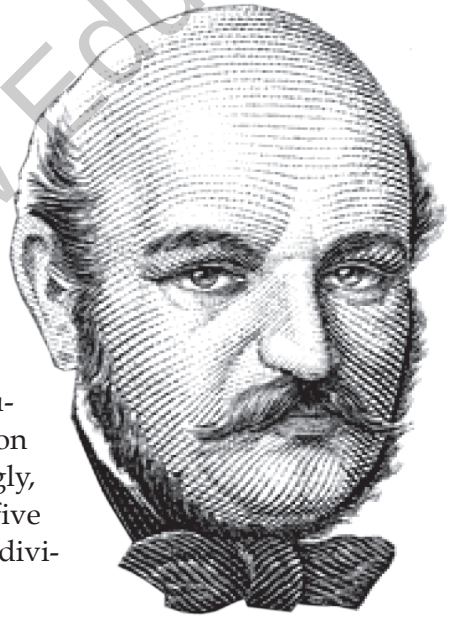

Image Credit: Engraved stamp issued October 25, 1960, by the Hungary Post, showing Ignaz Semmelweis (1818-1865). Wikimedia, *http://commons.wikimedia.org/wiki/File:1318_Portrait_60.jpg*

Questions

1. What were Semmelweis's initial observations?
2. What was the problem at hand?
3. What possible explanatory story might Semmelweis come up with?
4. How might Semmelweis test his suspicions?

Part II

One day, Semmelweis and some of his colleagues were in the autopsy room performing autopsies, as they often did between deliveries. They were discussing their concerns about death rates from childbed fever. One of Semmelweis's friends was distracted by the conversation and punctured his finger with the scalpel.

Days later, Semmelweis's friend became quite sick, showing symptoms not unlike those of childbed fever. His friend's eventual death from the illness strengthened Semmelweis's resolve to understand and prevent childbed fever.

Questions

1. What might Semmelweis now propose as an explanatory story?
2. How could Semmelweis test his new hypothesis?

Part III

In an effort to curtail the deaths in his ward due to childbed fever, Semmelweis instituted a strict hand-washing policy among his male medical students and physician colleagues in Division I of the ward. Everyone was required to wash their hands with chlorinated lime water prior to attending to patients. Mortality rates immediately dropped from 18.3% to 1.3% and in fact not a single woman died from childbirth between March and August 1848 in Semmelweis's division.

Questions

1. What conclusions can be drawn from Semmelweis's experiment?
2. How might Semmelweis revise his original hypothesis or experiments to gain additional information?

Part IV

Despite the dramatic reduction in the mortality rate in Semmelweis's ward, his colleagues and the greater medical community greeted his findings with hostility or dismissal. Even after presenting his work on childbed fever (technically named puerperal sepsis) to the Viennese Medical Society, Semmelweis was not able to secure the teaching post he desired, so he returned to Hungary. There, he repeated his successful hand-washing attack on childbed fever at St. Rochus Hospital in Budapest. In 1860, Semmelweis finally published his principal work on the subject of puerperal sepsis, but this too was dismissed. It is believed that the years of controversy and repeated rejection of his work by the medical community caused him to suffer a mental breakdown. Semmelweis died in 1865 in an Austrian mental institution. Some believe that his death was, ironically, caused by puerperal sepsis.

Questions

1. When presented with what appears to be unequivocal evidence in support of hand washing, why might Semmelweis's colleagues have dismissed his ideas?
2. How else might Semmelweis have approached the problem of disseminating his research findings to ensure their acceptance?
3. What, if any, role did serendipity play in Semmelweis's story of childbed fever?

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Chapter 16

A Need for Needles: Does Acupuncture Really Work?

Sarah G. Stonefoot and Clyde Freeman Herreid

The Case

Janet sat in her car in the driveway of her mother's house and eyed the front yard, which was completely taken over by a vegetable garden. It was possible that somewhere in there her mother was hidden, picking over her prized vegetables. Her mother was a bit eccentric. Actually, the word *crazy* sometimes came to Janet's mind when considering her mother. But she never said it out loud. This was her mother, after all.

Janet took a deep breath and then grabbed the door handle. It was time for another lunch with her mother, a meal that would inevitably turn into an argument.

Audrey greeted her daughter at the door even before Janet had a chance to knock.

"Why, hello, darling."

Janet was carefully unhooking a tomato vine from her foot before her mother noticed. She looked up and greeted her with a sense of apprehension.

"Hello, Mother."

"Oh, Janet, it's so nice to see you. Isn't it just a gorgeous day today?" Her mother was bubbling over with her usual happiness and high spirits.

"It's hot", Janet grumbled, "too hot".

"Well, come on in. I've just put together a delicious salad for lunch."

Salad again, Janet thought. She was glad she had stopped at McDonald's on the way over. She forced a smile and followed her mother into the house.

Lunch went well, until Audrey decided she couldn't hold her idea back any longer. "I was reading that magazine you got me the other day."

You will be divided into groups: half of your group will search for the pro literature (supporting the use of acupuncture) and the other half for the con literature. Be sure you understand the theory behind acupuncture, the different treatments acupuncturists might use and the evidence or lack thereof that suggests acupuncture may work, including the argument that any positive results are due to the placebo effect.

When you return to class armed with evidence, your job will be to work out a consensus consultative opinion for Dr Ramirez in your group and share that opinion with the rest of the class. Part of that sharing will involve the soundness of the evidence. Then you will need to work out among yourselves what you think Dr Ramirez should do.

A good place to start your research would be the web page "Acupuncture Information and Resources", National Center for Complementary and Alternative Medicines, on the US National Institutes of Health website (*http://nccam.nih.gov/health/acupuncture*).

Teaching Notes

Introduction and Background

Acupuncture is at least 2000 years old. It is a form of therapy in Asian medicine, part of a complete medical system that also includes herbology, physical therapy, dietetics and special exercises. It is the most widely used healing system on Earth, having first appeared in China and extending from there throughout Asia, Europe and North America.

Practitioners of acupuncture claim that qi (pronounced chee) is an energy force running through the body. It includes all essential life activities. Qi is composed of two opposites, yin and yang. These opposites must be kept in balance to sustain a healthy life. Yin represents the female, cold, dark, passive and medial part of the body. Yang is the opposite of the yin, encompassing the male, warm, light, active and lateral aspects of the body. The qi travels along special pathways of the body known as meridians. The meridians are 12 main pathways on each side of the body. The channels are named after 12 main organs; however, the pathways are not limited strictly to that organ. In acupuncture, the needles are inserted at points along these pathways. The points are where the meridians come to the surface. The aim of acupuncture is to adjust the vital energy of the body so that the correct amount reaches the proper part of the body at the essential time. This improves the body's ability to heal itself.

Acupuncture has been used to treat a variety of ailments, including lower back problems, cervical spondylosis, condylitis, arthritic conditions, headaches, allergic reactions, drug addictions, endocrine disorders, mental disturbances, heart failure, attention deficit hyperactive disorder, immune disorders, carpal tunnel syndrome, cerebral palsy, hay fever and menopause.

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Critics argue there is no solid answer as to how acupuncture might work. The hypothetical energy patterns of qi have not been demonstrated, nor have they been studied to a great extent in Western medicine. This leaves the theoretical foundation of acupuncture very much in question. In tests where acupuncture has been evaluated, it has been difficult to set up proper control groups. People undergoing acupuncture know what is supposed to happen. Thus, results from the procedure may be due to the placebo effect.

This case is intended for an introductory college-level science course such as human biology. It does not require the students to have an in-depth knowledge of the medical procedures of acupuncture or the central nervous system. However, it would be helpful for the students to have a general knowledge of the systems of the body. Students should also be aware of some of the general scientific guidelines used in evaluating scientific data, which will help them evaluate the theories behind the acupuncture procedure.

Objectives

This case is intended to expose students to one of the procedures advocated by therapists of alternative and complementary medicine, acupuncture. Students are asked to take a sceptical look at the procedure in an effort to see where the boundaries may exist between the believers of these alternative therapies and the scientific facts. The overall objective of the case is to expose students to the possibilities of alternative and complementary medical therapies, as well as to encourage them to question their effectiveness.

Students evaluate information on both sides of the issue to determine if there is adequate scientific information to conclude that acupuncture is a helpful method of treatment. During the case, students collect information from internet sources or journal publications with an emphasis on carefully evaluating the credibility of the information they collect.

The major blocks of analysis addressed by the case include

- theories of pain and the body (qi, yin, yang, meridians)
- methods of acupuncture
- needles, electroacupuncture and ear acupuncture
- theories regarding how acupuncture works (gate theory, central nervous system and endorphins)
- side effects
- ailments
- trials that have been conducted on patients
- criticisms and evaluations of the believers.